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NOISE GENERATION AND TRANSMISSION IN JASPER NATIONAL PARK

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled, "Noise Generation and Transmission in Jasper National Park," submitted by Benjamin Etan Fanta in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

The proliferation of human activity in Jasper National Park, associated principally with rising recreation and transportation demands, is placing severe pressures on the natural Park environment. This thesis analyzes a pervasive by-product of this activity--the propagation and transmission of noise.

Noise production was monitored and subsequently evaluated using the dB(A) scale, a weighting network that simulates the auditory response of the human ear. The perception of sound and noise is dependent on both the physical properties of sound waves, and the psycho-acoustical response displayed by the listener.

Jasper townsite and the Athabasca-Miette River valley system were sampled in order to identify noise sources and to ascertain their contribution to the existing noise environment. Through noise diffusion, this artificial environment has been superimposed on the natural ambient sound system operating in the area.

Seasonal changes exert a strong control on both the level of activity and the related noise generation; a major fluctuation in noise intensity and range coincides with the change from tourist season to off-season period.

Meteorological factors, particularly thermal and wind gradients, create a complex sound field in the valleys

through the refraction of sound waves. The diffusion of noise is further complicated by the interference resulting from the attenuation produced by topography and vegetation.

The noise factor can detract from the aesthetic values of the natural Park environment. It can potentially degrade this environment by altering the habits, composition, or distribution of wildlife in the Park.

The control of noise generation and distribution would require the implementation of a comprehensive zoning scheme. Noise as an environmental factor has largely been disregarded or gone unrecognized in the process of park planning. The preliminary work undertaken in this study needs to be expanded and augmented in both scope and detail if control is to be achieved over this detrimental by-product of human activity in the parks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Since its establishment in 1907, Jasper National Park has experienced many of the trends and conflicts that have characterized the development of a national park system in Canada.

Socio-economic and political realities of the latter part of the 19th century were not very conducive to the development of a well planned and integrated national park system. The frontier characteristics of Canadian society and history, and the seemingly limitless wilderness areas did not provide for a very high priority in the national scheme for the establishment of such a system. Its growth usually depended on economic justification. Jasper National Park owes its origin and early development, as do most of the mountain national parks, to the construction of a transcontinental railway system. The interest displayed by government and railroad in the parks at this stage was based on the economic returns to be derived from the development of an international tourist trade, catering to an exclusive and prosperous clientele (Nicol, 1970).

The promotion of the parks as a major Canadian tourist attraction has remained a primary factor in the history of the system. In addition to the economic incentive, the parks were seen as the means of providing a national playground to fulfil the public's recreational demands. The concept of national

parks as forming part of a Canadian heritage to be preserved for future generations, and serving as nature and wilderness sanctuaries was subordinated to the more lucrative exploitation of the area under the 'resort' concept. Consequently, commercial concessions and residential leasing was promoted, leading to the accelerated growth of townsites within some of the parks, and land uses that were often inconsistent with the principles of national parks (Nicol, 1970). The ambiguity and lack of firm guidelines that have characterized national park legislation has allowed a misdirected utilization and a general public misconception as to the real value and functions the parks should and were intended to provide.

A major change in government attitude and policy, emphasizing the need for environmental preservation in parks, has developed in the last decade. This has occurred at a period when increasing public mobility, leisure time, and recreational demands and needs have been placing intensified pressure on both government and parks to provide additional facilities and space.

In the case of Jasper, these factors have resulted in a greatly increased visitor attendance and traffic flow, as well as in the accelerated growth of commercial and recreational facilities. Figure A shows the rapid rise in visitor numbers that has occurred in the 1960's. The completion of a modern highway network toward the end of the decade allowed for a great influx, including tourists from intensely-used

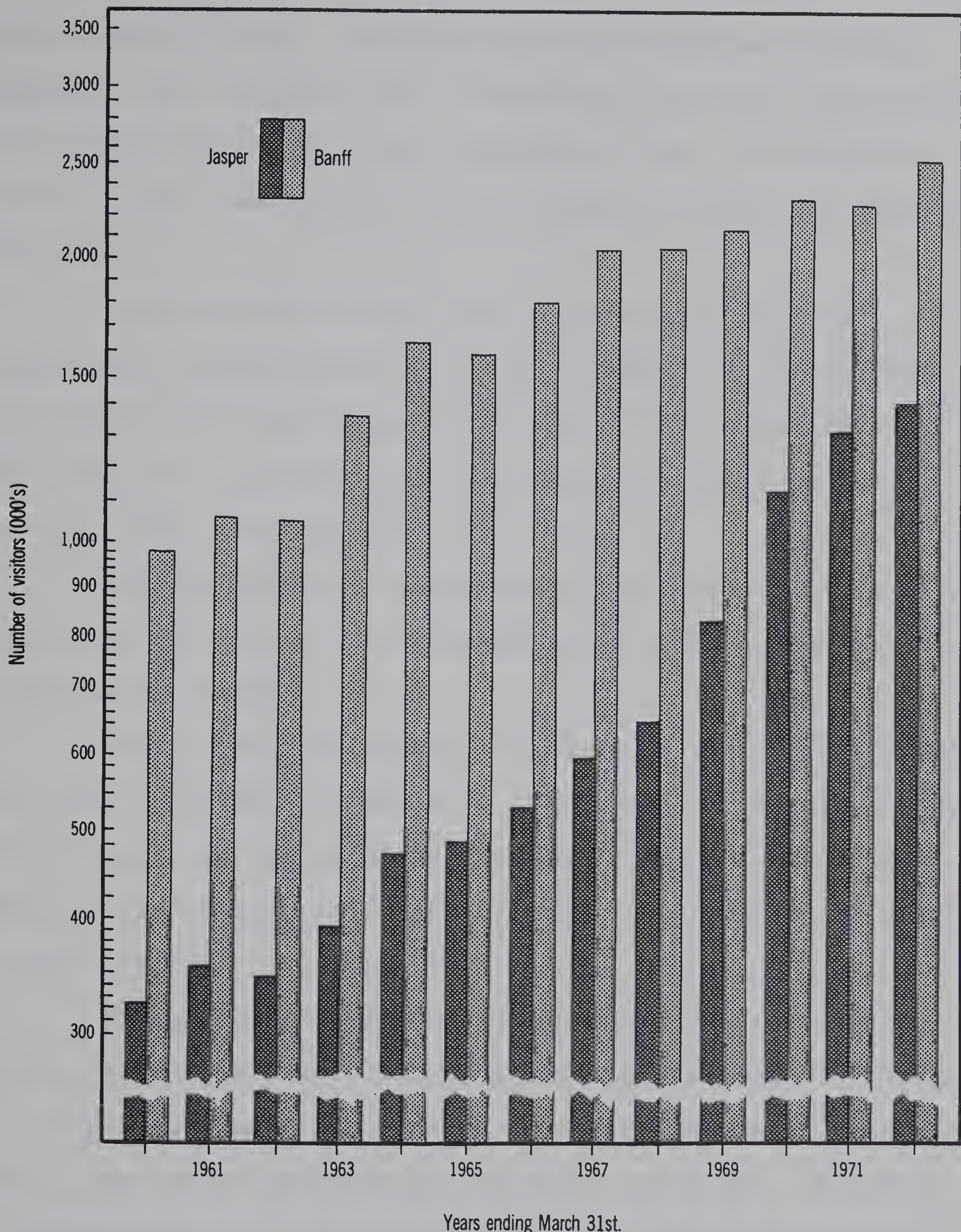


Figure A:Visitor attendance in Banff and Jasper National Parks.

Source:Canada,Visitor Services,National and Historic Parks Branch,
Department of Indian Affairs and Northern Development.

Banff National Park. Increased skiing development further augmented the incoming flow. Commercial vehicles, utilizing the highway system as a link between the west coast and the interior have been adding to the congestion caused by private traffic.

Intensified activity has subjected the park to increasingly severe pressures. This study is concerned with the analysis of noise production--one of the by-products of this activity, and evaluates its potential impact on the natural Park environment.

The physical and psycho-acoustical properties of sound and noise, as well as the measurement of these phenomena, are presented in Chapter 1.

Measurement and sampling techniques used in the Jasper study are outlined in Chapter 2. The scope of the noise survey is developed and the problems imposed by the existence of complex sound fields in the study area are discussed in detail in that chapter.

The noise production originating in Jasper townsite and the Athabasca-Miette valley system is analyzed in Chapter 3. Noise sources are evaluated to determine their contribution to the noise environments in those locations. Patterns of noise generation and distribution are outlined and mapped. The diffusion characteristics of noise in the valley system are studied, with particular reference given to the attenuation produced by topographic obstructions and forest cover.

The results obtained from the analysis are then used in Chapter 4 in discussing the potential ramification of the noise factor in terms of the natural Park environment. Interference with the enjoyment of a natural experience, and the degradation of the environment through the effects on wildlife are put forward as the two main issues of contention. Effective noise control would require the strict regulation of noise production and distribution through a comprehensive and well managed zoning plan.

A summary of the work and results of the thesis is presented in Chapter 5.

CHAPTER 1

SOUND AND NOISE

1.1 The Concept of Sound and Noise

Vibration of particles of any medium produces a disturbance throughout the medium due to the sequential transmission of the motion of one particle to others in the form of a wave. In the case of air, vibration produces a variaation in normal atmospheric pressure. This disturbance is transmitted to the ear, where the complicated auditory mechanism translates the vibration into the sensation called sound.

A distinction is needed to differentiate between the physical and the subjective or psychological aspects of sound. Stevens and Davis (1966) apply the term dimension to the physical sense of sound as applied in acoustics, and define it as being the vibration or transmitted vibration of particles in a gas, liquid, or solid.

Sound can also be defined as "the stimulus to hearing" (Boring, 1935), but a precise definition of the stimulus for the various aspects of auditory sensations is difficult to derive since each stimulus to any aspect is a complex function of several variables. The distinction with the physical dimensions of sound lies in the fact that the latter are measured against an instrument scale, whereas, in

analyzing the aspects of a stimulus, a subjective judgment is made about the physiological effects of the stimulus on the ear (Stevens, 1935).

Thus, frequency and intensity (Appendix 1) are physical dimensions of sound propagation, and they exist whether or not the sound impinges on a human ear. Pitch and loudness are psycho-acoustic assessments of these dimensions, respectively, made by a human observer, and can not exist unless such an observer responds to a sound (Rodda, 1967). For example, Middle 'C' exists only as a frequency of 256 cycles per second (c/s) until some ear hears the sound and assigns to it the pitch designated as Middle 'C'. Similarly, the physical intensity of an 80 hertz (Hz) tone may be 70 decibels (dB), and remains such until it is assigned a loudness level of 60 phons by a human observer who responded to the sound.

The complexity factor in sound evaluation can be held constant, and the functions of the various attributes of hearing can be expressed graphically on plots whose co-ordinates are frequency and intensity (Stevens and Davis, 1966). These dimensions form the basis for the discussion of sound and noise measurement in this thesis (section 1.2), since all psychological and physiological qualities can be explained as functions or derivatives of these two variables (Beranek, 1954, Hirsh, 1952).

In the measurement of noise, and in the evaluation of its effects, the physical parameters are supplied by the physicist or acoustical engineer, to whom noise "is a sound

whose character can be defined and whose properties can be measured with the same equipment that measures other sounds" (Peterson and Grosse, 1967). The social application of such evaluation has led social scientists to give a qualitative definition of noise - defined as being an undesired sound. Glorig (1958) points out that the "essential characteristic of noise is its undesirability": noise is commonly defined as an annoying or unwanted sound. The factor of undesirability can be expressed in terms of consonance and dissonance which are described by Krech and Crutchfield (1958) as being, respectively, "the quality of harmony, smoothness, or unity of combination of tones, often experienced as agreeable," and "the quality of disharmony, illfittingness, and lack of unity of combination of tones often experienced as disagreeable." However, these are definitions based on perception and subject to variation in interpretation:

> While dissonance may increase the probability of a sound being classified by the perceptual system as noise,... dissonance and noise are not synonymous. The final classification, however, will be the additive effect of many systems, internal and external to the organism.... We can think of the human observer as having a variable tolerance level for sounds: if the sound crosses this tolerance level it is classified as noise, but whether or not this occurs is a function of the observer as well as the auditory stimulus (Rodda, 1967).

Obviously, the evaluation of sound as constituting a noise is a value judgment based on the complex interrelation of an individual's situation, perception, experience, frame of reference, personality, and other determining factors.

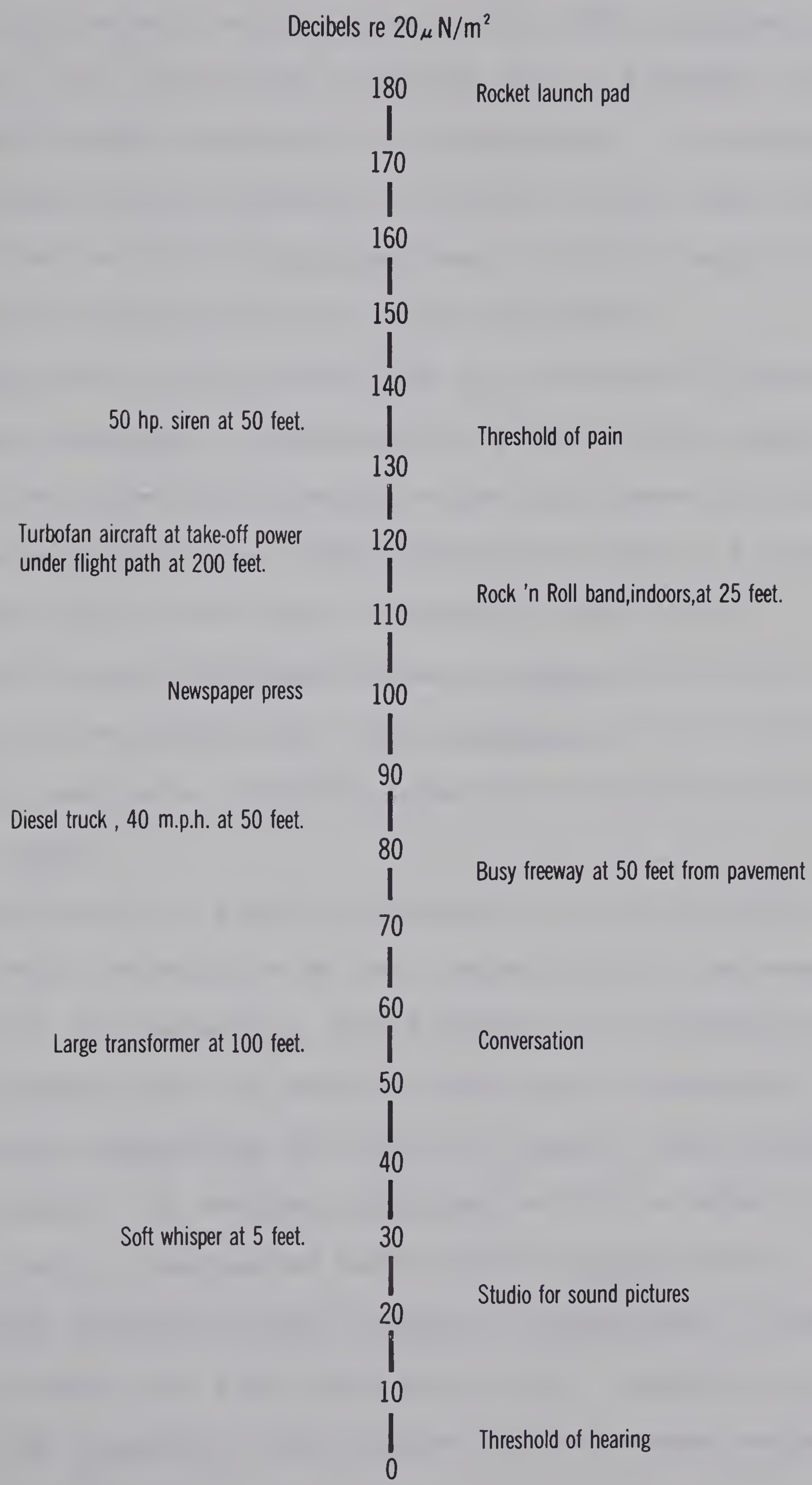
The apparently unavoidable association of noise and

human activity, and the resultant noise environments produced by such association, create problems which provide a legitimate and increasingly important field of investigation for the environmental scientist.

1.2 The Measurement of Sound and Noise

The change in pressure associated with the disturbance of particles in air is measured by the extent of this change, and by the rate at which it occurs. The extent of the variation is called the sound pressure (SP), a force per unit area caused by the sound wave vibration, and is measured as dynes per square centimetre (dyne/cm^2) or the equivalent value in units of microbars. The 'average' range of human hearing in terms of sound pressure is approximately 0.0002 microbars to 200,000 microbars (Davis and Silverman, 1970). To overcome the problem of representing this billion to one range on a linear pressure scale, a logarithmic scale of relative sound pressures is used; values are given in decibels, a term representing a sound pressure level (SPL) --an expression of the ratio of a particular sound pressure with respect to a reference sound pressure. For air-born sounds, the reference value is usually given as 0.0002 microbars--the minimum auditory threshold for normal young adults. An equivalent reference level is given as 20 micronewtons per square metre (20uN/m^2); both reference levels are assigned the pressure level of zero decibels. Figure 1.1 represents the typical levels for various noise sources

Figure 1.1:Typical A-weighted sound levels for selected noise sources.



and noise environments. A soft whisper registers at 30 dB, and has an equivalent sound pressure of 0.0063 microbars; 60 decibels, the sound level pressure near a freeway, has a corresponding sound pressure of 0.2 microbars. A newspaper press produces 20,000 microbars or 100 dB, while the sound pressure level of 180 dB produced near a rocket launch pad corresponds to a pressure of 200,000 microbars.

The rate at which variation in atmospheric pressure occurs (the frequency) is measured in terms of the number of times that a periodic quantity--the sound wave in this case--repeats itself in a given interval of time. A frequency of one cycle per second (c/s) is termed a hertz (Hz). Frequencies can be classified as being <u>sonic</u> (20-20,000 Hz), <u>ultrasonic</u> (above 20,000 Hz), and <u>infrasonic</u> (below 20 Hz). Most hearing and noise exposure problems are associated with the sonic range.

Reaction to a sound is dependent on the overall sound pressure level, as well as on the composition of the sound as a function of frequency. The frequency distribution of the sound energy over the audible range can be analyzed by electronically separating the acoustic energy into various frequency bands. An analysis of three sounds is shown in Figure 1.2 using a series of bands called <u>octave</u> bands, each of which covers a 2-to-1 range of frequencies. A band level is produced for each particular band. Lines A, A_1 represent the frequency distribution for two tones having

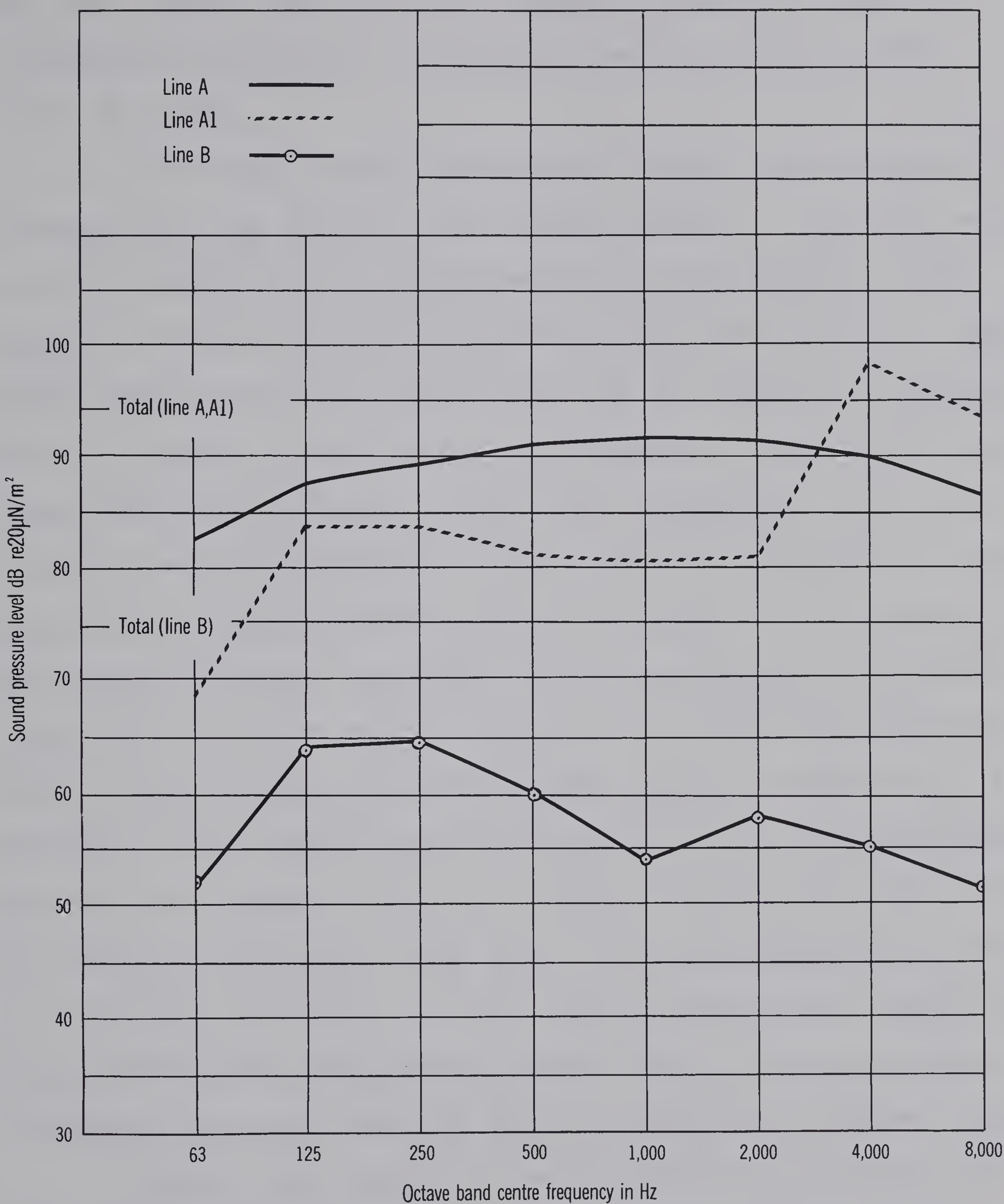


Figure 1.2:Octave band analysis of three sounds. Lines A,A1 represent the frequency distribution for two tones having the same total sound pressure. Line B represents the distribution for the noise produced by a calculating machine.

Source:Bauman,1971, Peterson and Gross,1967.

the same total level of 98 dB. Line B represents the distribution produced by a calculating machine with a total level of 74 dB.

The sound fields produced by various sound sources are dependent on the type of waves being emitted. Spherical waves radiate equally in all directions from a theoretical point source. Plane waves radiate from a large sound source. Free field conditions exist where there are no reflecting surfaces in the vicinity of the source, and where no interference exists from other sound sources. Under such conditions, the sound pressure level produced by a point source is the same in every direction at equal distances from the source. The pressure amplitude decreases from the source according to the inverse square law where the sound intensity is halved for each doubling of the distance from the source--usually expressed as a decrease in the sound pressure level of 6 dB. A single measurement of the pressure level at a known distance from the source can establish what the sound field will be, provided the output at the source is known. In the case of plane waves under free field conditions, the pressure level does not decrease with increasing distance from the source (Peterson and Gross, 1967).

Usually such idealized sound fields do not exist in an outdoor noise environment. Media are not 'ideal' and sound waves dissipate with distance. Energy is lost with such dissipation, and the amplitude is decreased. Thus, the amplitude of plane waves does decrease with distance, and the decrease for spherical waves is greater than predicted

by the inverse square method (Beranek, 1954). The requirements for ideal conditions will usually not be met due to variation in atmospheric conditions, and interference from other sound sources or surfaces nearby; these factors, acting alone or in conjunction, could produce a semi-reverberant or a totally <u>diffuse</u> sound field. Moreover, sound sources are not usually simple point source emissions, but complicated plane wave sources where sound is not radiated uniformly in all directions. In such cases, directional waves are produced which are subjected to the same deviation from ideal conditions as the spherical and plane waves (Beranek, 1971).

The effect of change in the apparent loudness of a sound due to variation in frequency response, is incorporated into sound measuring equipment by providing <u>weighting networks</u>, the three most common being the 'A', 'B', and 'C' scales, shown in Figure 1.3. The A-weighted dB scale, designated as dB(A), provides a good approximation of the ear's perception of sound at moderate levels. The dB(A) scale selectively discriminates against low frequency energy, and to a lesser degree, against high frequency energy. It thus conforms to the variation in apparent loudness produced by different sounds set at moderately low intensity (Subcommittee on Vehicle Noise, 1970). The dB(A) network also describes the damaging auditory threshold shifts which occur at high pressure levels, de-emphasizing the less dangerous low frequency sounds. Easily determined by the use of a sound level meter, the dB(A) scale is the best available

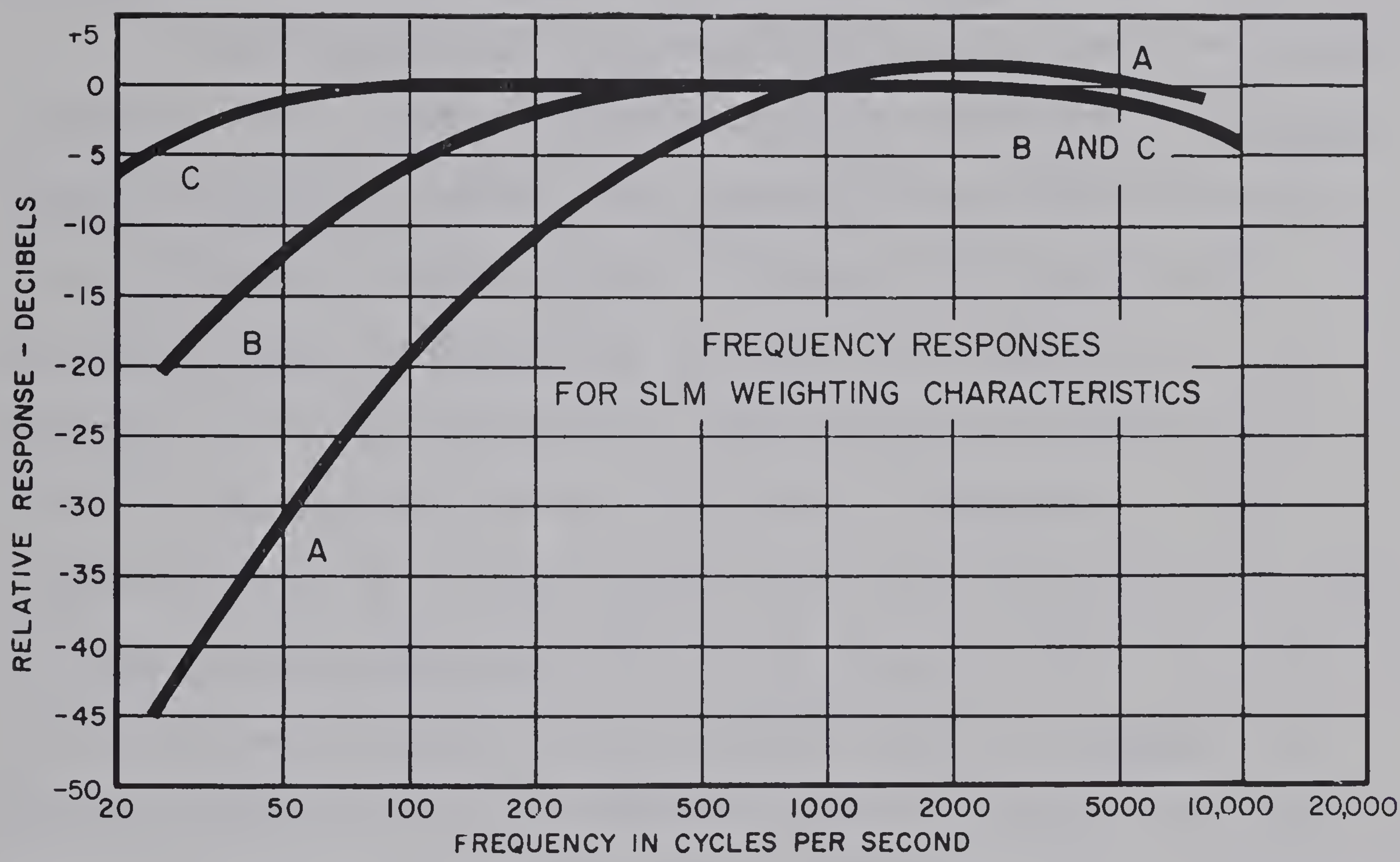


Figure 1.3: Internationally standardized frequency response for general purpose sound level meters.

Source: International Electrotechnical Commission, IEC/123-1961.

standard for setting and enforcing noise legislation (Land and Jansen, 1970). It must be remembered that when a weighting network is used, measurement is in terms of sound levels; only when the total flat (linear) response is measured, are sound pressure levels being monitored.

Psycho-acoustical classification of a sound as constituting a noise, involves rating sounds according to loudness level or loudness rather than scaling on an absolute basis. A set of equal loudness levels contours which has been internationally standardized is shown in Figure 1.4. The method is derived principally from the work by Barkhausen (1926), and consists of the subjective comparison of the loudness level of a given sound with that of a 1,000 Hz tone of known sound pressure level. The intensity of the 1,000 Hz tone has been defined as the loudness level in phons, the diagram showing how the loudness levels of pure tones with constant sound pressure level vary with frequency. Proceeding from this relationship, it can be seen, for example, that according to the 50 dB contour, a 59 dB level at 100 Hz is just as loud as a 50 dB 1,000 Hz tone. Similarly, it can be found that a 50 dB 100 Hz tone approximates the 38 dB 1,000 Hz tone. A determination of loudness, based on the psychological response of an observer to loudness level ratios of sounds, has been developed in terms which classify sounds as being 'soft' or 'loud.' The relationship between loudness, measured in sones, and loudness level is shown by the scale in Figure 1.4; it is based on the fact that a two fold change in

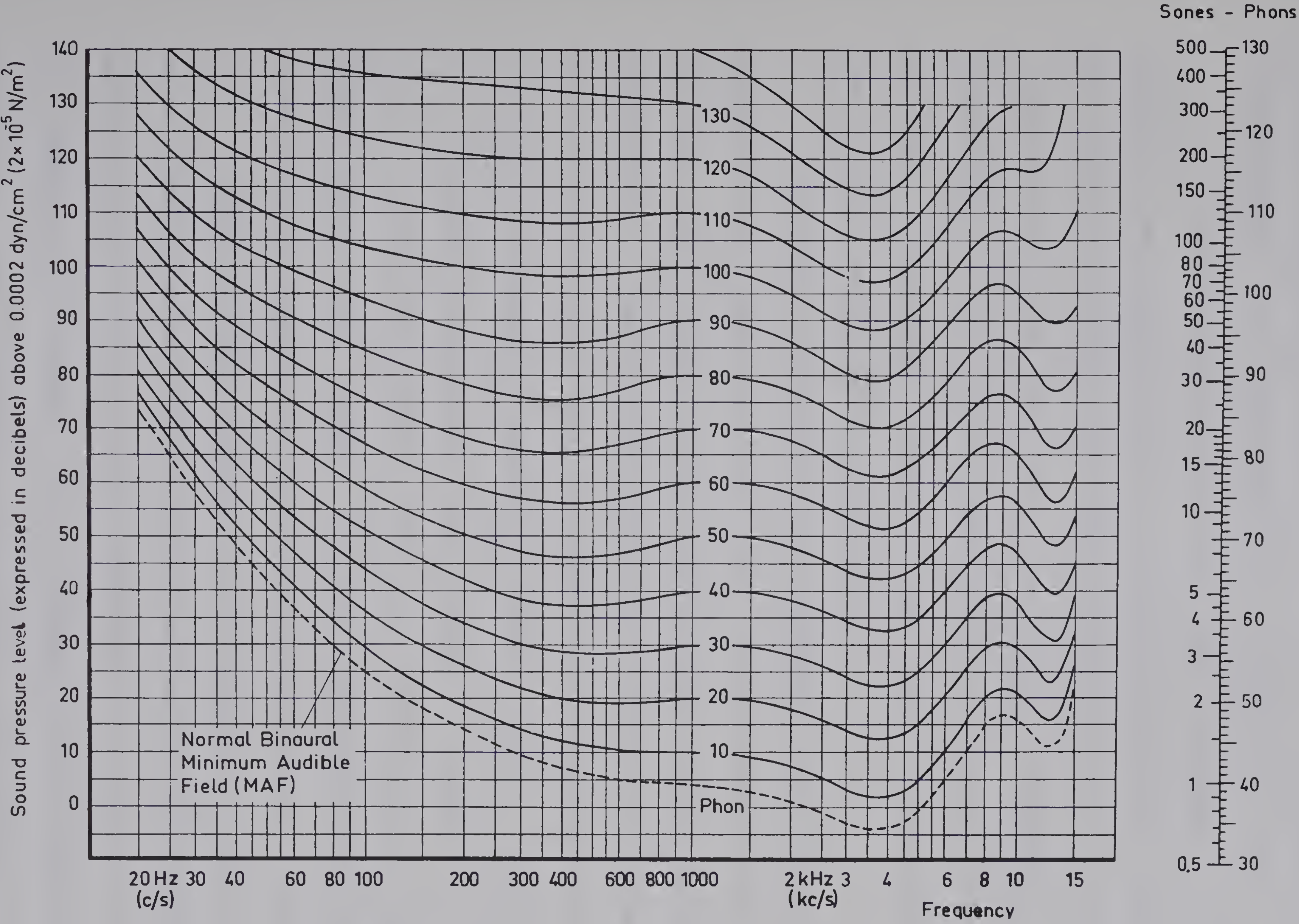


Figure 1.4: Normal equal loudness contours for pure tones and normal threshold of hearing under free field listening conditions. Conversion scale for loudness level in phons and loudness in sones is included on the right.

Source:International Organization for Standardization, ISO/R226-1961.

loudness equals a change in sound intensity of 10 dB (phons), and can be expressed as $S = 2^{(p-40)/10}$ (International Organization for Standardization, ISO/R 131-1959).

Various procedures have been developed to further explain the relationships of psycho-acoustical phenomena. The underlying basis for these derivations is the energy distribution of a sound as a function of frequency. A knowledge of this distribution gives a better estimate of the probable subjective effects of the sound than simply knowing the overall sound pressure level.

Unlike the concept of loudness, the concepts of <u>annoyance</u> and noisiness have not been firmly established, and do not seem, at present, to be predictable from measured physical parameters. The many psychological aspects involved in annoyance determination makes it difficult to define and measure a largely perceptual concept (Kryter, 1970). Kryter (1959) has attempted to quantify the concept of noisiness in relation to aircraft induced noise, by developing the <u>perceived noise level</u> scale (PNdB); to date, this scale has been successfully applied only in conjunction with aircraft noise.

Broch (1969) summarizes the general trends for annoyance effects, even though these can not be physically scaled. Annoyance is related to the loudness of a sound; when a sound is judged to be louder, it is normally also judged to be more annoying. High frequency (or pitch) sound appears to be more annoying than sound having its major intensity distributed in the lower frequencies. If the sound is intermittent,

irregular, or rhythmic in nature, it would probably be considered as more annoying than a sound with the same physical dimensions -- or even the same loudness -- that has a 'steady' occurrence. Finally, the location of sound in relation to the listener is important in determining annoyance; if the sound source is fixed and can be, furthermore, located by the observer, it will generally be less annoying than if it moves and can not be localized (diffuse field).

CHAPTER II

THE NOISE ENVIRONMENT IN JASPER NATIONAL PARK

2.1 Noise Sources

The distinction between sound and noise as presented in Chapter 1, can be applied to the particular situation of Jasper National Park by distinguishing, on the one hand, between sound environments, and, on the other hand, noise environments. The sound environment of the Park refers to the ambient levels produced in a natural setting by any element or combination of elements within such a system. The sound produced by wind in trees, or by falling water provide examples. A noise environment--for the purpose of this study--is produced by an interjection of human activity into a natural setting, a superimposition of noise on the sound environment. Both the motor vehicle and hiker are elements of the noise environment, although they differ in their contribution to the noise environment in terms of intensity and impact. Noise environments are intrusions into the natural sound environment of the Park.

Human activity and its noise production in the Park can be divided into three main categories:

(a) Urban-centered activity, comprising administrative, commercial, transportation and residential functions, and their multivaried interaction.

(b) Transportation activity, including road, rail, and air networks.

(c) Recreation activity, a broad category including all outdoor-oriented activities and facilities which emphasize the use of the physical habitat of the Park; water-based sports, hiking, and camping are examples.

It should be emphasized that the above classification has been devised simply as a convenient method for a logical and substantive monitoring system. While some activities fit into one or other of the categories exclusively, others might fit into more than one. Jasper Park Lodge (inset map) exemplifies the latter situation. An extensive and sophisticated physical plant, infrastructure, and indoor activities gives the Lodge an urban aspect. Yet, it is a resort, owes its existence to the physical setting of the Park, and can be classified as a recreation activity. Thus, although based on interpretation, the classification is not arbitrary, and serves the primary purpose of encompassing all human activities under a logical system for the monitoring of noise production.

2.2 Noise Monitoring

The problem of analyzing a complex and varied noise environment in a limited time period, necessitated the concentration of samples on what appeared to be--by field observation, and a series of random samples--the most relevant and outstanding sources of noise production in the Park. The problem of limiting the scope of analysis was

exacerbated by the negligible documented research on this type of noise study application, and the consequent lack of guidelines.

The need to concentrate the sampling resulted in locating the study area in the Athabasca-Miette rivers valley system, primarily within a five mile radius of Jasper townsite (inserted map-North Sheet). The natural tendency for human activity to be concetrated in valley locations in the Park is evident in this case. The valley system has provided a historic passage through the Rocky Mountains, and the gap continues to be utilized by modern-day transcontinental transport systems. In conjunction with secondary expansion associated with the functioning of the Park, and an increasing recreation demand, this utilization has produced the heavy 'tunnel' development in the area, with Jasper townsite acting as the focal point.

Sampling involved monitoring noise with a sound level meter on the flat scale, and recording the noise on a sensitive tape recorder. A graphic trace was produced using the dB(A) scale for analysis (Appendix II).

Jasper townsite was monitored as an urban noise source. Ten sampling locations were chosen to give an evenly-distributed areal coverage (Figure 2.1). After testing for level uniformity, readings of fifteen minutes duration were taken for the mid-day period (1200 to 1400 hours) and evening (1900 to 2100 hours). A total of eighty readings were used in determining daily as well as seasonal variation in noise

Figure 2.1. Location of sampling points in Jasper townsite.

production.

A valley transect was carried out in the Athabasca River valley along a bearing through the townsite. Noise samples were taken at thirteen sites, shown in Figure 2.2, to determine the propagation of noise in this section of the valley.

A second transect was taken in the Miette River valley, involving eight sites (Figure 2.3). Monitoring was specifically directed at transportation noise originating from the Yellowhead Highway and the Canadian National Railways line.

Several samples were obtained at both the East and West Gates of the Park in order to record the noise produced by decelerating and accelerating heavy trucks and semi-trailers.

It was often possible to monitor more than one activity at any sampling site, either concurrently, or separately. Thus, both transportation and urban noise sources were studied in the Athabasca valley transect. Similarly, sites seven and eight in the townsite were used to monitor trains heading east and west under different conditions of grade. Differences in the noise production for cars and commercial vehicles were recorded by using both urban and transect sites.

A number of sites were used in an attempt to evaluate the noise attenuation characteristics of topographic features which involve a break of slope and, as a consequence, provide an obstruction in the line of sight to a noise source(s).

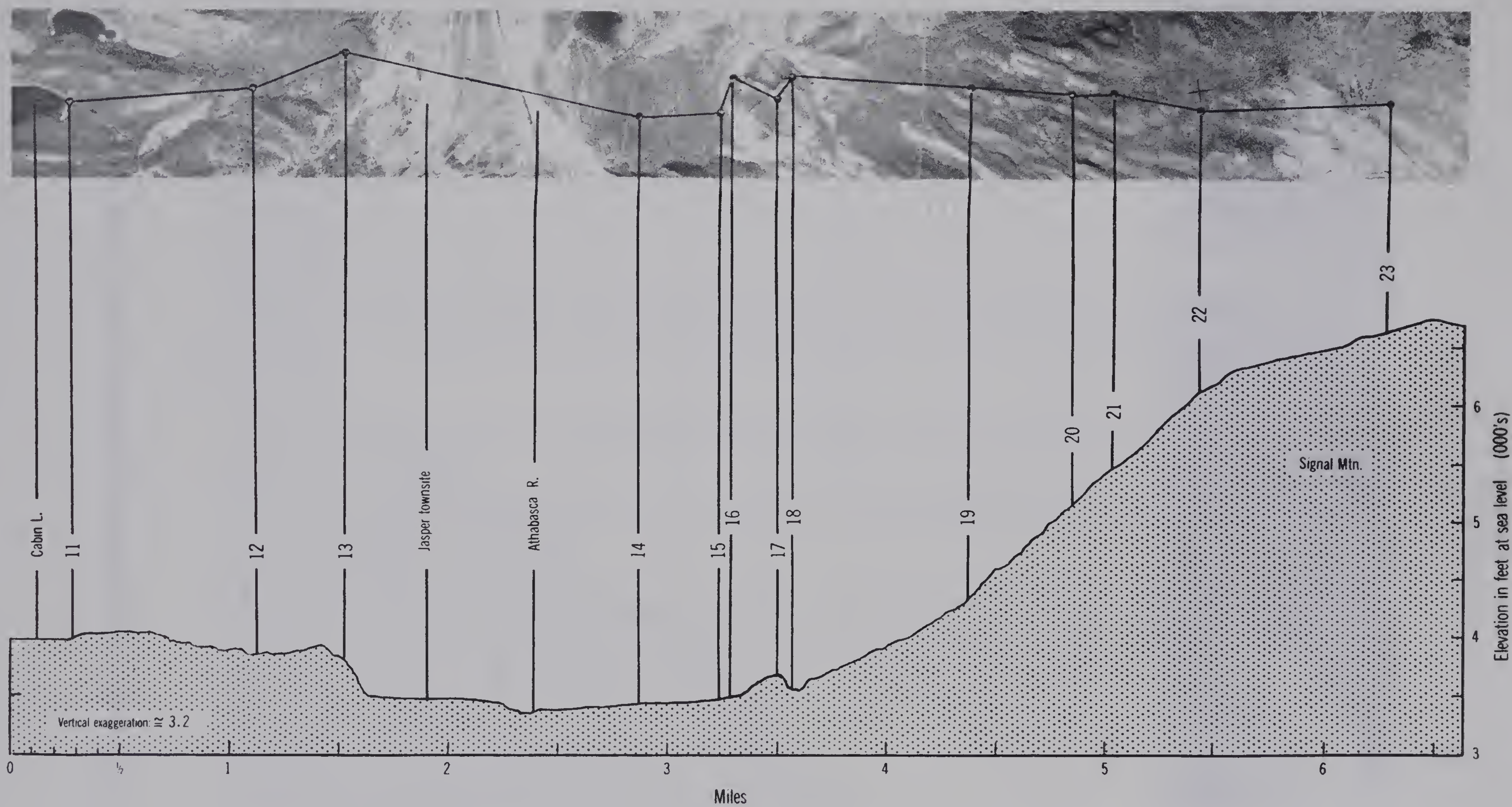


Figure 2.2. Athabasca River valley transect in plan and profile, showing the location of sampling sites.

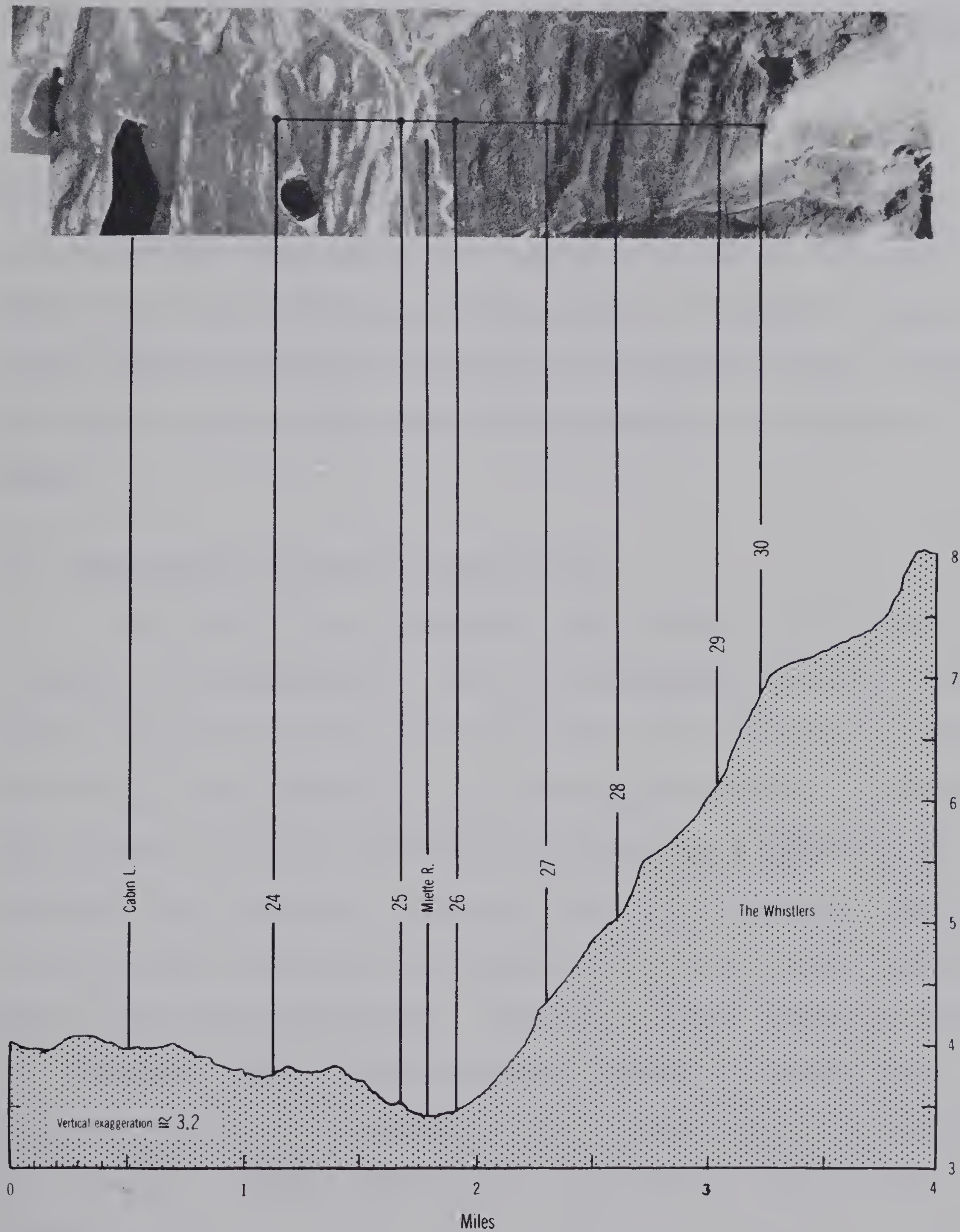


Figure 2.3. Miette River valley transect in plan and profile, showing the location of sampling sites.

A similar evaluation involved the attenuation characteristics of varying vegetation cover, with particular emphasis placed on sites fifteen to eighteen in the Athabasca valley transect.

In all instances, potentially significant factors (weather conditions, aspect, elevation, etc.) were noted; whenever these appeared to be relevant to the particular case, they were included in the analysis. In all, a total of one hundred fourteen samples were analyzed in this study and used to derive the information presented in Chapter Three.

2.3 Monitoring a Complex Sound Field

The lack of an automatic sound meter, to be used as a control on measurements, made it unfeasible to relate noise levels measured at any particular site to an absolute level produced at the source(s). In the absence of such a control, any estimate of the attenuation produced as a function of distance would have had to be made on the assumption that point or directional sources were present in the area, and operating under free field conditions. Testing for the inverse square law operating under such conditions failed to produce the predicted values. It appeared, that rather than an idealized free field, a complex sound field operated in the valley system.

Sound waves from a variety of directional sources, some stationary and others in motion, would tend to produce sound interference, either by competing for the same air

space, or by being out of phase with each other. When acting in conjunction these waves would amplify the levels; when acting in opposition to each other, the waves would diminish levels, or distort sounds. At any particular instant, a site may intercept an unknown combination of interfering waves.

Aside from wave interference, various factors influence the outdoor propagation of sound. Sound waves are affected by the constant movement of the atmosphere through which they pass; turbulence, temperature, and wind gradients, as well as reflection from various surfaces combine to change the intensity, and cause fluctuations in the sound received at a particular site. The longer the transmission path through the air, the more variable the average amplitude, and the greater the fluctuations in the intercepted sound (Kurze and Beranek, 1971).

Although it is beyond the scope of this study to determine the actual contribution made by various factors in producing the particular sound field in the Athabasca-Miette valley system, several of these factors would appear to be particularly important and deserve further discussion.

The speed of wave transmission in the atmosphere varies with temperature: At 0 degrees Centigrade, the speed of sound is 1,087 feet per second; at 100 degrees, the speed is 1,266 feet per second. Due to this variation in velocity, waves will be bent (refracted) when passing from one air mass to another with different temperature characteristics. In some cases, temperature differences can be extreme enough to cause

total reflection, the dividing line between the air masses becoming a barrier to the sound wave. In the case of the valley system being studied, site location ranged over a vertical distance of about one kilometer (3,300 to 6,600 feet above sea level). Aside from the temperature gradient that would exist in the valley due to the environmental lapse rate, vertical thermal stratifications would probably exist due to the uneven heating and cooling of the air in the valley. Moreover, temperature variation would be further increased by the localized effect of slope heating of the air. The total result of these variations would be a thermal distortion of an already complex sound field in the valleys.

Wind noise proved to be a consistently severe problem in the actual monitoring process. The usual positive wind gradient that exists near the ground, that is, an increasing wind velocity with height, operated in the valley system. Wind velocities were increased by the channeling effect of segments of the valley system on the predominant westerly flow of air. On exposed slopes in such areas, winds often reached twenty miles per hour, while at high elevations, thirty miles per hour winds were not unusual. Wind noise is produced by the turbulence set up when the wind blows past the microphone on the sound meter. An increase in the velocity produces an increase in the noise intensity (Figure 2.4). The top curve represents the noise level produced by wind flowing past a microphone as a function of velocity: The bottom curve results when monitoring is done with the addition of a

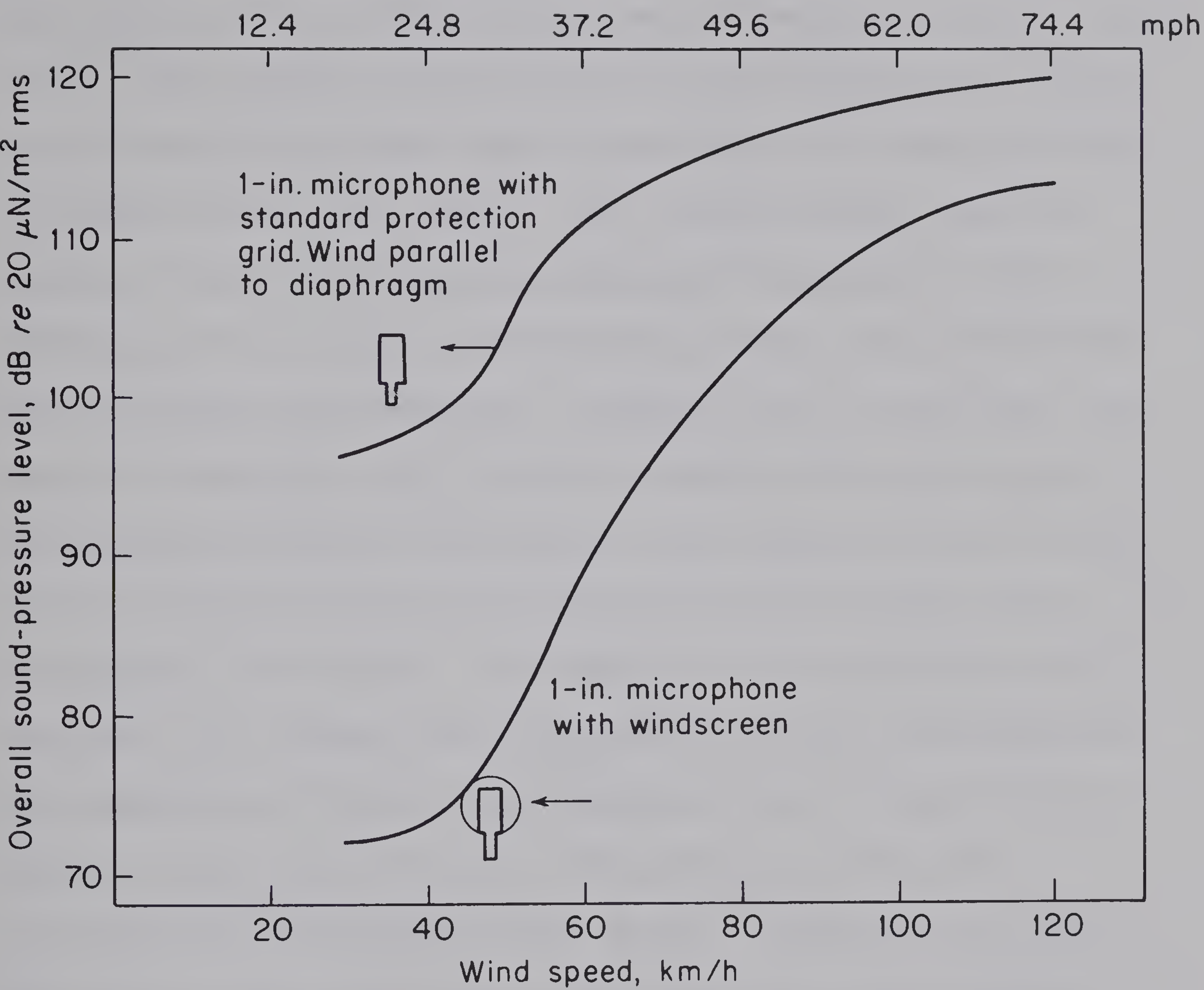


Figure 2.4: Wind noise as a function of wind speed.

Source:Bruce,1971

spherical wind screen. Both microphone and wind screen are of the type used in this study. If the turbulent noise reduction for a given microphone-windscreen combination is known, it can be determined whether the measured noise levels are caused by the wind, or are due to the noise source (Bruce, 1971). The levels are measured with and without the screen. If no change occurs for the two readings, the desired level was measured at both times. If a change occurs that is equal to the experimentally determined turbulence noise reduction, it is assumed that both readings have been dominated by wind interference. A change that is less than the expected reduction would make the reading for the exposed microphone the level produced by wind noise, and the level recorded for the screened microphone would be the level produced by the source. In testing for interference, differences for screened and unscreened readings approximated the experimental values for locations where strong, consistent winds were observed, indicating the dominant influence of wind noise on the meter. Screening in sites with small wind velocities eliminated wind interference: Unfortunately, when recording at 'quiet' locations, wind gusting--a common phenomenon in valley bottom sites--tended to re-introduce wind noise into the sample.

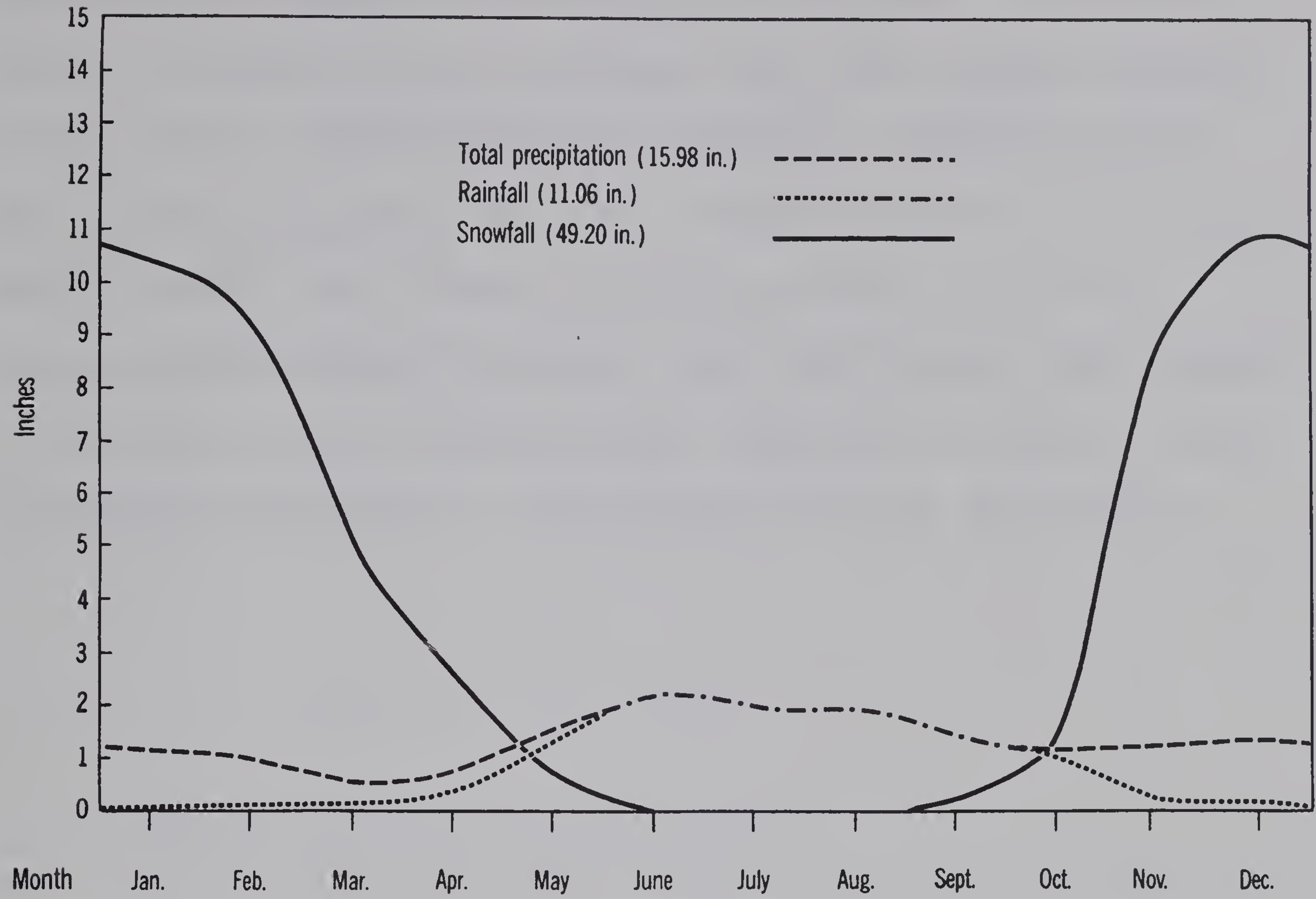
As in the case of thermal gradients, wind gradients tend to cause refraction of sound waves. Upwind of a sound source the gradient tends to bend the waves upward, creating a 'shadow zone' into which sound penetrates only by

diffraction (using a barrier to produce a second set of waves), or by turbulence (Kurze and Beranek, 1971). Downwind, the waves are bent downward, and intensify the surrounding levels.

The illustrated complexity of the sound field in the study area, can be visualized, by considering the interrelationship of two of the varied factors influencing the sound field--temperature and wind gradients--for a hypothetical case (Kurze and Beranek, 1971). In the presence of a strong negative temperature gradient (large lapse rate), and low wind speed, a noise source may be completely surrounded by a 'shadow zone.' The same source can radiate symmetrically as in a free field when a strong positive temperature gradient exists (an inversion), and under conditions of low wind velocities. These situations could potentially operate in the case of isolated noise sources in the study area, under conditions of clear, hot, afternoons, and clear, calm, cold nights, respectively--these being the times when the appropriate gradients could best be expected to exist.

The other major problem in sampling involved the difficulty of recording during periods of heavy rainfall; the sound produced by rain often prevented the sound level meter from registering noise production. Mean monthly values for rainfall, snowfall, and total precipitation at Jasper townsite are given in Figure 2.5a. Averages are based on a thirty year period (1930 to 1960). Total precipitation is the sum of the rainfall and the water equivalent of the snowfall, the latter taken as one tenth of the depth of snow. Monthly precipitation values for the year 1971, when field research was

Figure 2.5a. Mean monthly rainfall, snowfall and total equivalent precipitation in Jasper townsite.



Source: Canada, Meteorological Branch, Department of Transport.

Figure 2.5b. Monthly rainfall, snowfall and total equivalent precipitation in Jasper townsite for 1971.

being carried out, are given in Figure 2.5b. The water equivalent is measured directly in this case. The distribution of values in both diagrams show the tendency toward a high summer concentration of rainfall. Since the major part of the field work for this study was carried out in the summer season, this factor of high rainfall, plus the unpredictable mountain weather, and the frequent occurrence of localized heavy precipitation, combined to cause a major interference problem in the process of noise monitoring.

CHAPTER 3

NOISE PRODUCTION AND NOISE SYSTEMS

3.1 The Urban System

Jasper townsite is the focal point for human activity in the Park. A study of the townsite was carried out to determine the noise environment produced by this urban development. Major noise sources were identified, and their contribution to the production of noise was analyzed in terms of spatial and seasonal variations.

3.1.1 Sampling Method and Limitations

Analysis of the noise environment in the townsite was mainly based on the data derived from the ten sample sites for the time periods of 1200 to 1400 hours, and 1900 to 2100 hours. The noise generated in both weekday and weekend situations was monitored during July and early November, 1971. The data from the recordings is presented in Tables 3.1a, 3.1b, and 3.1c.

The mean noise level, or average intensity for any particular recording (Table 3.1a) is related to the corresponding range variation during the trace history of that sample (Table 3.1b). The mean becomes increasingly significant as a representation of the noise level for an individual recording as the extent of the range decreases, and as noise intensities tend to cluster around this average

TABLE 3.1a. MEAN NOISE INTENSITIES FOR TOWNSITE SAMPLES

		JULY				NOVEMBER			
		WEEKDAY		WEEKEND		WEEKDAY		WEEKEND	
Site	Zone	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100
1	R	65	64	62	60	55	52	53	52
2	R	66	67	69	64	62	62	60	57
3	R	67	65	63	72	60	62	61	61
4	R	53	61	64	63	59	55	58	56
5	C/R	70	73	74	73	63	60	64	64
6	C	76	77	80	79	70	68	69	65
7	C	80	80	81	78	78	67	69	67
8	C	77	75	76	77	69	67	69	66
9	C/R	74	76	72	77	64	60	63	60
10	I	76	80	83	77	79	79	81	80

R = Residential C = Commercial I = Industrial

TABLE 3.1b. NOISE RANGE LEVELS FOR TOWNSITE SAMPLES

	JULY				NOVEMBER			
	WEEKDAY		WEEKEND		WEEKDAY		WEEKEND	
Site	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100
1	52-82	59-72	54-71	55-75	50-61	48-62	47-63	45-57
2	60-83	63-82	60-81	55-72	51-66	55-67	54-70	48-65
3	61-77	60-73	55-75	64-83	55-65	58-64	57-66	54-65
4	57-84	57-71	60-74	59-74	55-66	51-61	53-63	49-60
5	59-85	61-84	69-86	68-84	62-67	58-65	62-68	61-68
6	67-91	69-89	74-91	75-93	65-76	64-73	66-73	62-70
7	75-86	72-91	77-94	72-90	73-83	64-71	64-74	64-69
8	69-95	70-92	70-95	70-91	63-79	64-75	64-79	61-71
9	63-88	65-87	61-85	66-93	57-70	55-63	57-71	55-62
10	74-78	74-83	82-88	73-86	75-83	77-81	78-82	78-81

TABLE 3.1c. NOISE CLIMATE FOR TOWNSITE SAMPLES

	JULY				NOVEMBER			
	WEEKDAY		WEEKEND		WEEKDAY		WEEKEND	
Site	1200-1400 HRS.	1900-2100	1200-1400-HRS.	1900-2100	1200-1400 HRS.	1900-2100	1200-1400 HRS.	1900-2100
1	57-73	62-68	59-67	57-67	53-59	52-56	50-58	50-55
2	63-68	65-72	65-71	60-66	58-65	59-63	57-64	53-61
3	64-71	63-68	60-69	67-77	57-61	59-63	59-62	58-62
4	50-62	58-65	62-68	61-68	56-61	53-58	56-59	53-57
5	65-78	70-78	72-79	72-80	63-66	59-63	63-65	62-65
6	71-83	73-82	78-84	78-85	67-72	66-69	67-70	64-68
7	77-82	76-84	79-83	76-81	76-81	65-68	66-71	65-67
8	74-81	72-79	72-78	74-80	67-73	66-71	68-71	63-69
9	70-80	71-80	68-77	75-85	61-66	58-62	61-68	58-61
10	75-77	79-81	-83-	76-80	77-81	78-80	80-82	-80-

figure.

Table 3.1c has been included to augment the other two sets of figures, and to give a more comprehensive picture of the noise situation. The noise climate represents the range of sound levels recorded for 80 per cent of the time at each locality (the sound levels between 10 and 90 per cent levels). The 90 per cent level is used as an overall measure of the influence of 'distant' noise sources on the site being monitored. The 10 per cent level represents the contribution, both from a distance and at the site itself, of intermittent or incidental high intensity noise production. The use of the noise climate rating is particularly appropriate in this case where the sites, representing residential, commercial, and industrial land uses were located within an area of less than three quarters of a square mile. In spite of the buffer effect provided by buildings in the townsite (with a potential for a maximum shielding decrease of 15 dB when placed between a sound source and the meter [Wiener et al., 1965]), noise impingement occurred among the sites, and could be readily observed in several graphs. It had to be assumed that such interference might be present at all the sites as part of the 90 per cent level. The decreased range involved in utilizing the noise climate procedure should have reduced the extent of interference, and provide for more mutually independent readings; these should be based on noise characteristics that are representative of the locality being studied.

A certain degree of caution is necessary in interpreting the noise data. Since it was not possible to take simultaneous readings for the entire townsite, it can not be assumed that exactly the same noise environment was being monitored at any given time, in terms of either noise production, the existing noise field, or weather conditions. Thus values should not be taken as being absolute and emphasis should rather be placed on the general trends and patterns present in the noise environment.

3.1.2 Spatial Patterns

Differences for the noise parameters from site to site can be explained in terms of the variation in noise production existing among sites at any instant. The sites tend to form groups which show similarities in their noise characteristics according to the land use zone in which they are located. Sites 1 through 4, occupying residential areas (R), tend to form such a group. Similarly, sites 6,7, and 8, located in commercial zones (c), fall into a separate class. Sites 5 and 9, with a semi-commercial, semi-residential land use designation (C/R) appear to fall between the commercial and residential groupings. Site 10 has an industrial classification (I). The types of activity associated with the three zones will tend to produce noise sources which are similar in their noise output within each grouping, and distinctly different from group to group.

3.1.3 Transportation Noise in the Townsite

Noise associated with transportation activities constitutes an important segment of the total urban system.

Railroad activities provide the major transport noise source in the area. Jasper serves as a divisional point on the Canadian National Railways transcontinental line, regulating an area from Edson, Alberta, to Blue River, British Columbia. In addition to the regular passenger and freight traffic that passes through the Park, a large portion of the bulk freight from the Alberta Resources Railway is routed through the valley system. The shunting, stop-over, and passage of this combined traffic through the townsite produces the noise originating in the railway yard. Individual noise components generated by coupling, under-carriage movement and idling or running diesel units all contribute to the overall noise production. This noise was noticeable throughout the townsite, but was most intense in areas surrounding the railway yard. One discernible side effect was the rattling of window panes caused by noise-induced vibrations. The sounds produced by the railroad were most apparent at night or during other periods of a subdued ambient noise level. Figure 3.1 shows a set of graphs produced for site 7, representing both July and November readings. In both cases railyard activity was taking place in the form of idling or shunting diesel units. The consistent high levels produced by these sources can be clearly detected. The shunting diesel produced a distinctly

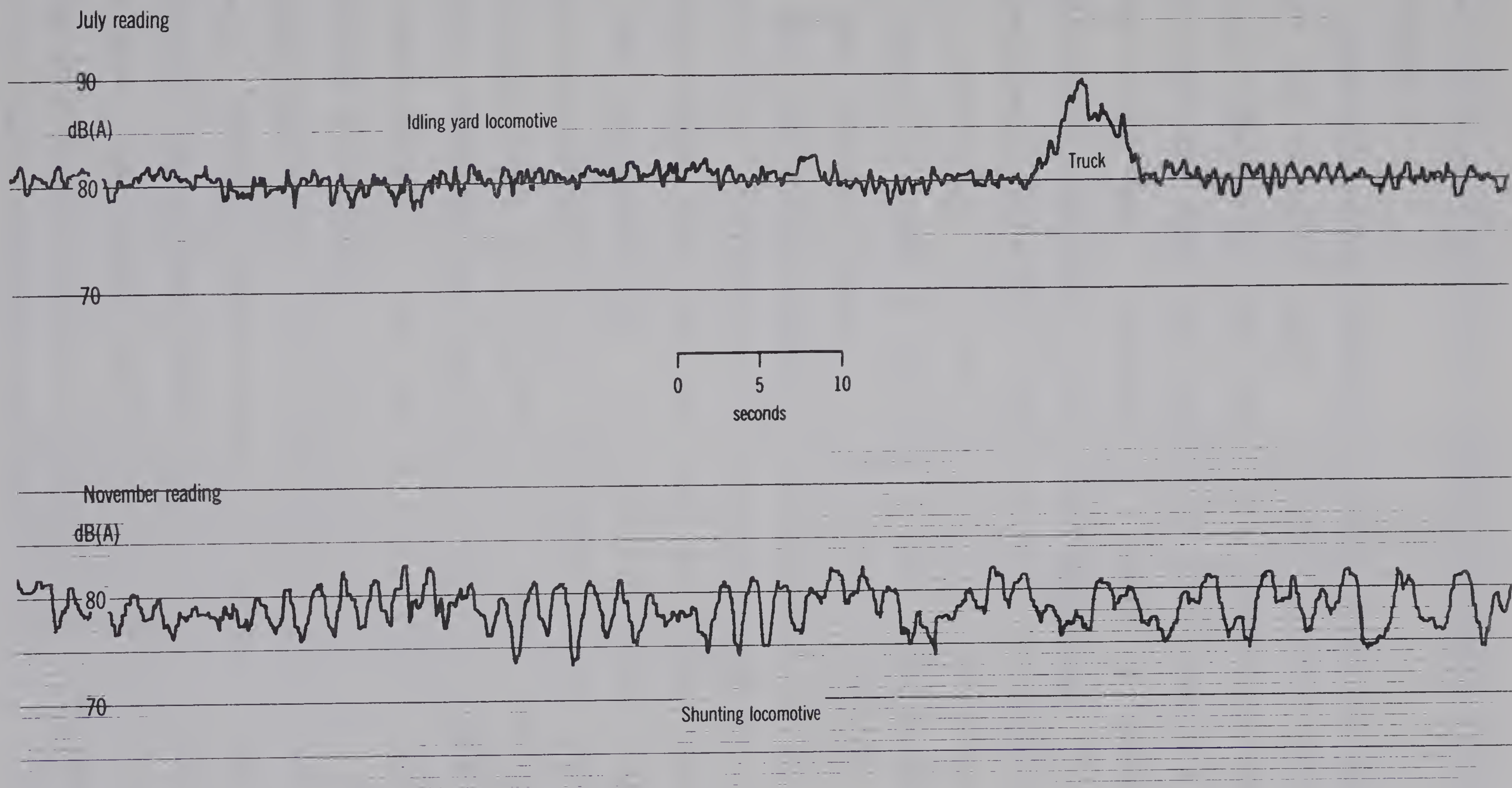


Figure 3.1. Railyard noise production as monitored at site 7 for the weekend period in July and November. The cyclical pattern in both traces is derived from the power output from idling or shunting diesel units.

cyclical trace with variations caused by changes in the power output.

Approaching and departing trains generated another distinct type of noise output. A major variation existed for trains approaching from the west as opposed to those arriving from the east, the difference being due to a larger gradient to the west. The graphs in Figure 3.2 represent the noise traces produced by the CNR Continental (a regular transcontinental passenger train) entering the townsite from opposite directions. In the case of the westbound train, a level stretch of track to the east of the townsite allowed for a fast approach, causing an abrupt meter response. The noise from the idling locomotive was suddenly replaced by a rapidly rising intensity due to the incoming train. The high intensity was of short duration, dropping rapidly as the train came to a quick stop. The trace represents a Doppler effect, where sound waves are compressed in front of the fast moving train, and elongated at the rear. This produced the rapid, short-duration peaking as the train passed the sound level meter. In the case of the eastbound train approaching the station, a major grade is involved; the descending train has a protracted breaking period and a slow approach. The noise of the idling yard engine is superseded gradually by the rhythmic power output of the incoming locomotive. The rhythmic pattern is interrupted by the train whistle at a level crossing, and diminished as the engine comes to a halt. Although the maximum intensity in both

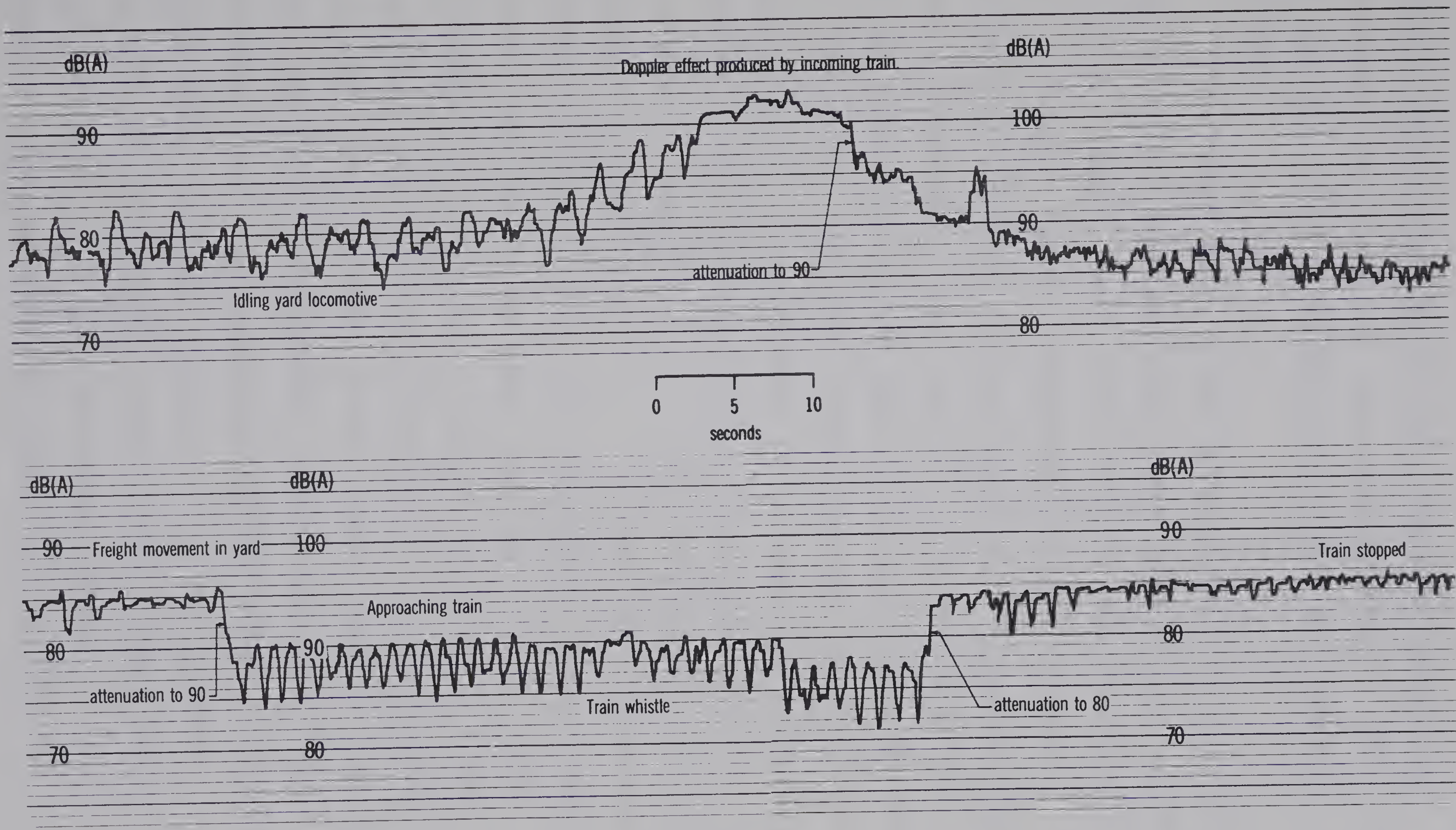


Figure 3.2. Noise produced by CNR Continental entering Jasper townsite from opposite directions.
Different track grades on the eastern (top trace) and western (bottom trace) approaches help determine the noise components being generated.

cases is about equal (92 dB [A]), the high levels were maintained far longer for the eastbound train. (The trace for the latter had to be spliced to show the complete sequence.)

The other major source of transport noise is the motor vehicle. Although some effect from traffic on the Yellowhead Highway makes itself felt in the townsite, it is of a 'muted' nature, largely due to the shielding provided by a cutting between the rail yard and the Athabasca river. The highway runs along the cutting between the river and the level site of the yard, and sound waves are reflected into the valley area east of the townsite. Most of the traffic noise in the townsite is derived from local motor vehicles. The noise contribution from this source is shown in the two graphs for site 8 taken during both the July and November periods (Figure 3.3). In the case of the July reading, traffic movement was responsible for the major portion of the total noise being produced. Two separate influences can be traced to traffic noise. The first represents the "Quasi-steady-state" noise distributed along a line of freely flowing traffic (Bolt, Beranek, and Newman, 1967), and gives a consistent rating that can be found in the background level. Superimposed on this level, "discrete moving noise sources," usually attributed to trucks, produce the high, isolated peaks in the graphs. These peaks were most noticeable in quiet residential areas, or during the November sampling period at sites where traffic was

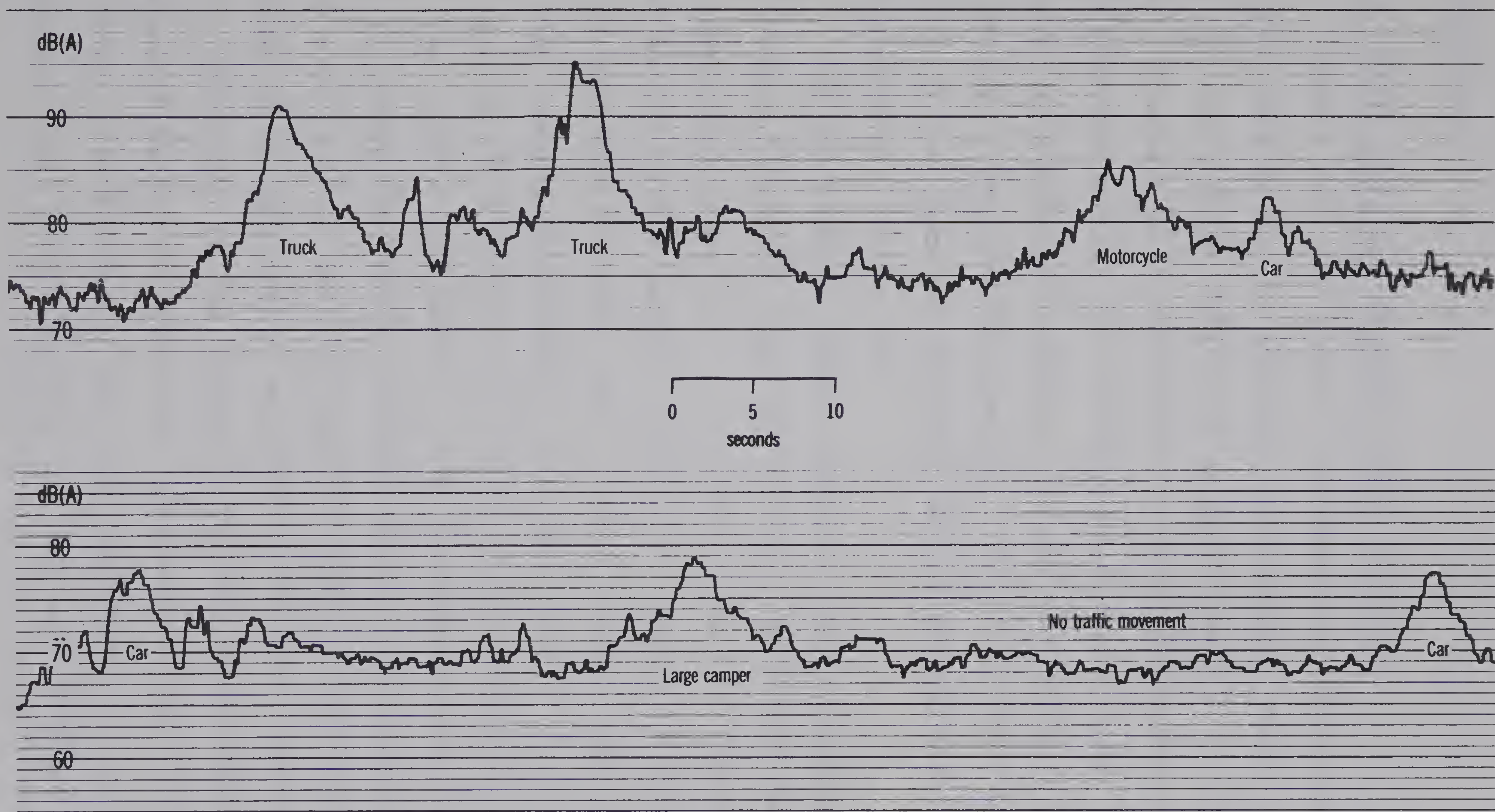


Figure 3 3. Noise production from local motor vehicle traffic as monitored at site 8. Readings taken for both summer (top trace) and fall (bottom trace) show the significant contribution from motor traffic to the total urban noise environment.

intermittent.

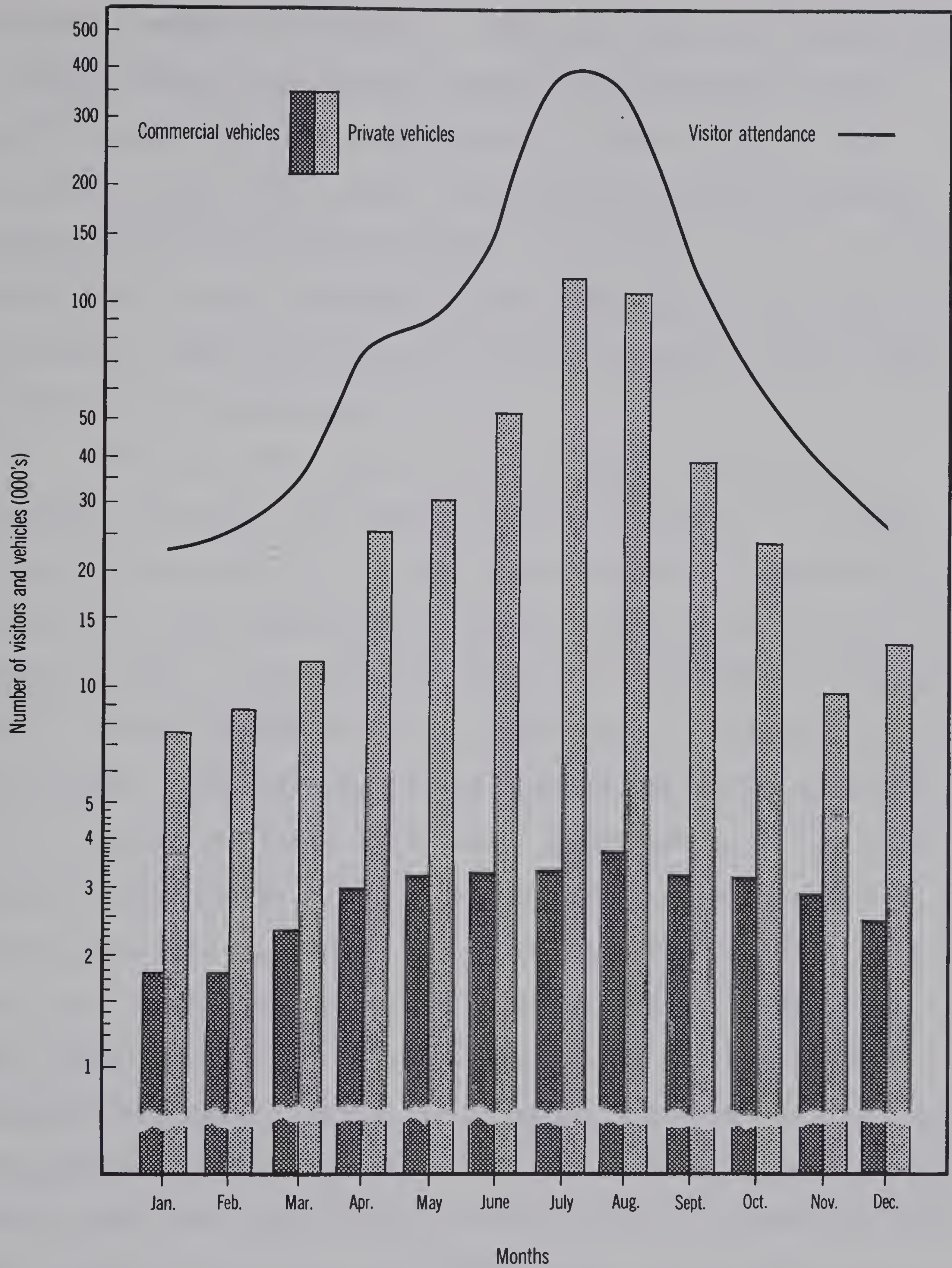
3.1.4 Short-term and Seasonal Noise Patterns

Apart from any spatial distribution, noise data for the townsite can be analyzed for patterns which vary with the eight major designated sampling periods. A basic aspect of urban noise environment is the fluctuation in noise production that can be expected to occur under the varying conditions, for example, of daytime versus evening, and weekday versus weekend periods. This is caused by changes in the level of activity, and is subsequently related to the land use in the area.

In the case of Jasper townsite, such fluctuation was not a major factor of noise production. Developed best in the commercial sites for the November series of samples, the fluctuations gave a general pattern of increasing and decreasing intensities at these and the other sites. This pattern was only vaguely developed for the July series of readings, and was not discernible in the case of the commercial sites for that month. The lack of large fluctuations of this kind, even at commercial sites, resulted from a total activity level which has an equally limited range of noise production. Although this explanation is valid in terms of the overall noise production in the townsite, it does not explain the absence of large variations for commercial sites in July. Nor does it help explain the large difference in noise production that occurs between the July and November series.

In fact, these two series reflect a major seasonal fluctuation in the noise environment, July corresponding to the major tourist season, and November falling within an off-season period. Individual samples for each period tend to show similar noise intensity and range characteristics--generally higher and larger in July than in November--and thus, form two major groups which coincide with the appropriate seasons. The uniformly high levels found in July at commercial sites completely replaced the normal daily fluctuations which operated at those sites (for example, site 7) in the off-season.

Seasonal variation is probably the outstanding feature of the noise environment in the townsite. The major tourist season in the Park occurs in summer, while a second less intensive season occurs in winter, in conjunction with the skiing period. This fluctuation in activity is indicated by the private vehicle flow in the Park during 1971 (Figure 3.4). Visitor attendance declines to its lowest level in winter, peaking in the spring skiing period, as well as in the summer tourist season. In the case of the townsite, the greatest single seasonal change involved an increase in the population from the permanent level for 1971 of 3,750 to a summer maximum of 5,000 (Visitor Services, Jasper National Park). This was mainly due to the large summer labour force employed in the service industries. A total of 1,571 rooms was available at this time for overnight accommodation to cope with the seasonal influx of tourists



Source: Canada,Visitor Services,National and Historic Parks Branch, Department of Indian Affairs and Northern Development.

Figure 3.4. Monthly visitor attendance and vehicle traffic in Jasper National Park during 1971.

(Jasper Chamber of Commerce). Moreover, the town attracted a daily daytime and evening crowd from surrounding areas, particularly from the campgrounds in the vicinity. The increased human and vehicle traffic flow into the townsite helped to create the consistently high noise levels recorded during the various sampling times. The highest and most protracted readings occurred in the commercial sites, where traffic was concentrated.

The patterns associated with major spatial and seasonal groupings are demonstrated in Figure 3.5. Trace histories are shown for sites representative of residential, commercial and industrial locations, using sites 4,6 and 10 respectively. Superimposed traces for the 1200 to 1400 hours weekend period for July and November are presented in each case. The different noise sources operating at each site, as well as their individual contribution to the total noise production is clearly demonstrated. Significant differences existed among the sites in terms of noise intensity and range. The greatest seasonal change occurred at the commercial site. In fact, the change at site 6 was greater than shown, since the November trace has an exaggerated fluctuation caused by wind gusting. During calm conditions, the range should reduce to two or three decibels. The industrial site did not undergo any significant seasonal variation, differences in the traces being attributable to a temporary shutdown of a refrigeration plant at the time of the November recording.

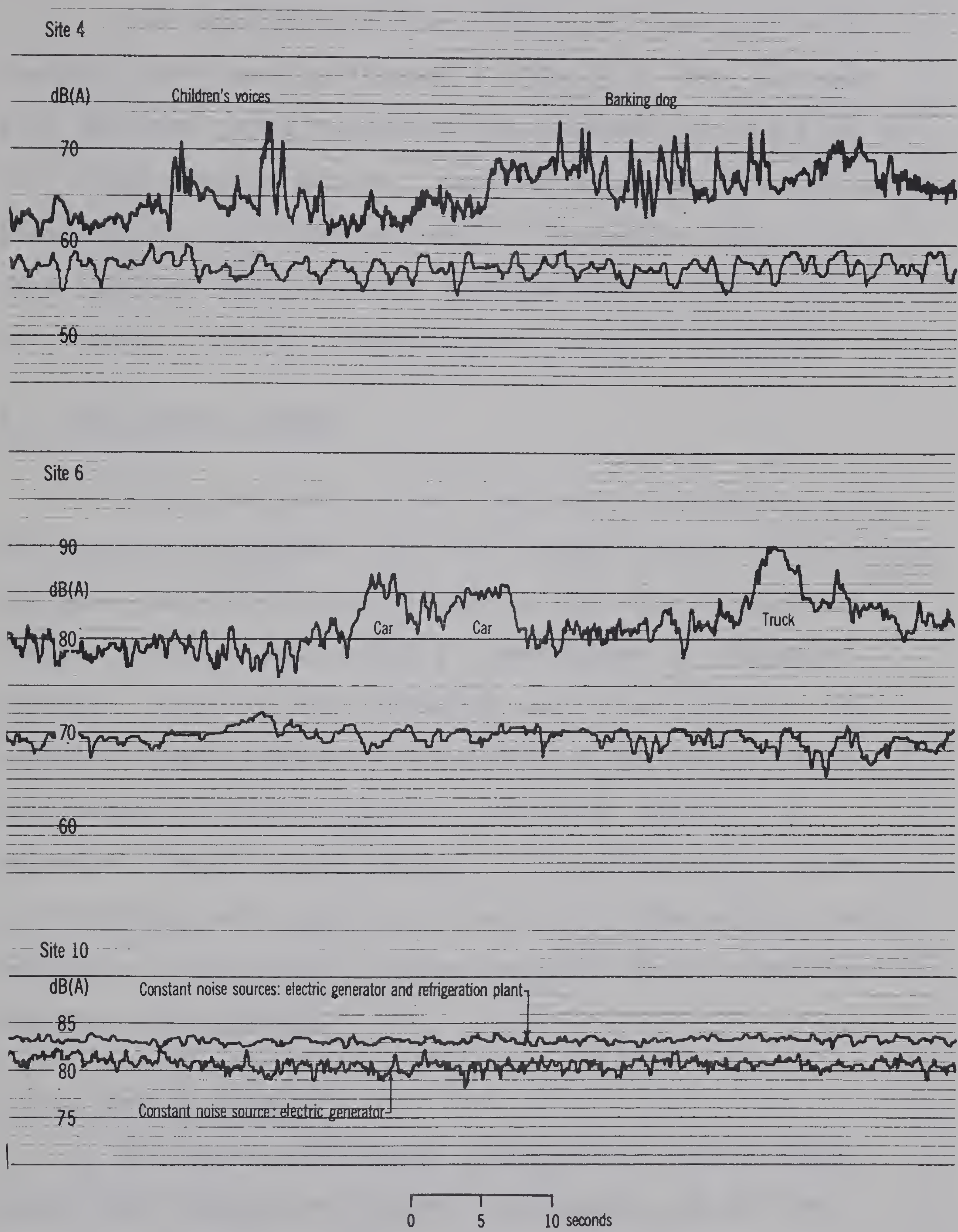


Figure 3.5. Spatial and seasonal variation in noise production at three sites representing residential (site 4), commercial (site 6), and industrial (site 10) locations in Jasper townsite. The top trace in each set of superimposed graphs represents the reading for the summer period; the bottom trace represents the reading for the fall period.

The overall patterns in July and November for the townsite are shown in Figures 3.6 and 3.7. The two maps give the mean noise intensity distribution for the 1200 to 1400 hours weekend period. Isolines are drawn connecting points having the same intensity. The noise contour maps thus produced give a visual representation of the spatial and seasonal patterns brought out through the samples.

3.2 The Valley System

As in the case of the townsite, the valley system was studied to discover the major noise sources operating in the area, and their contribution to the noise environment. Various sources, particularly those formed by transport networks, exist in both townsite and valley system. The townsite itself becomes a component of the valley noise environment by radiating noise into that system. An important factor in the valleys is the attenuation caused by topography and vegetation cover; the attenuation characteristics of both were analyzed as part of the investigation into the noise system.

3.2.1 Valley Samples

The noise environment study in the valley areas around the townsite was based, principally, on the two transects carried out in the summer of 1971 (Figure 2.2, 2.3). Data on the noise levels and ranges found at the twenty sample sites is presented in Table 3.2, and represent

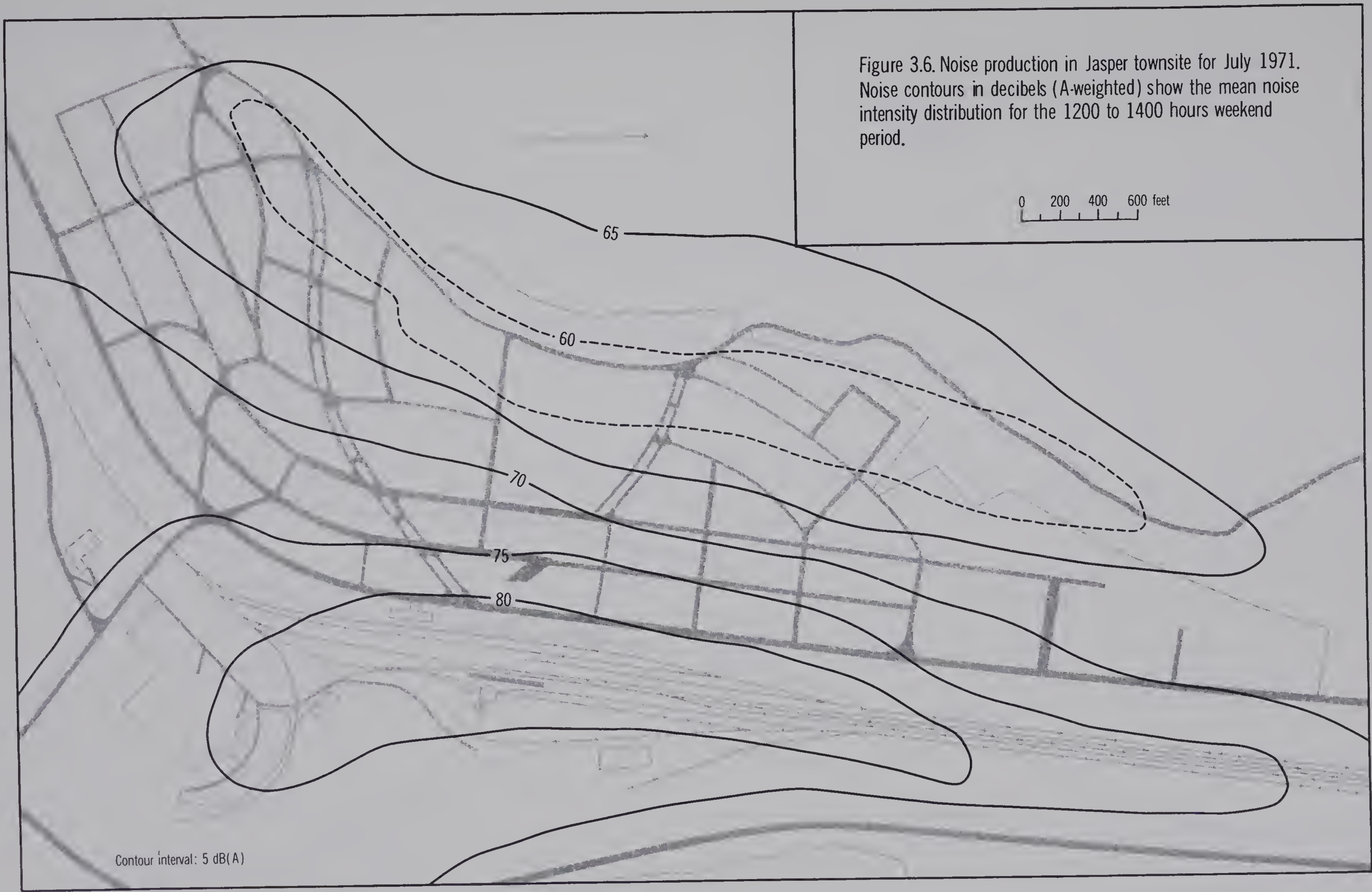


Figure 3.6. Noise production in Jasper townsite for July 1971. Noise contours in decibels (A-weighted) show the mean noise intensity distribution for the 1200 to 1400 hours weekend period.

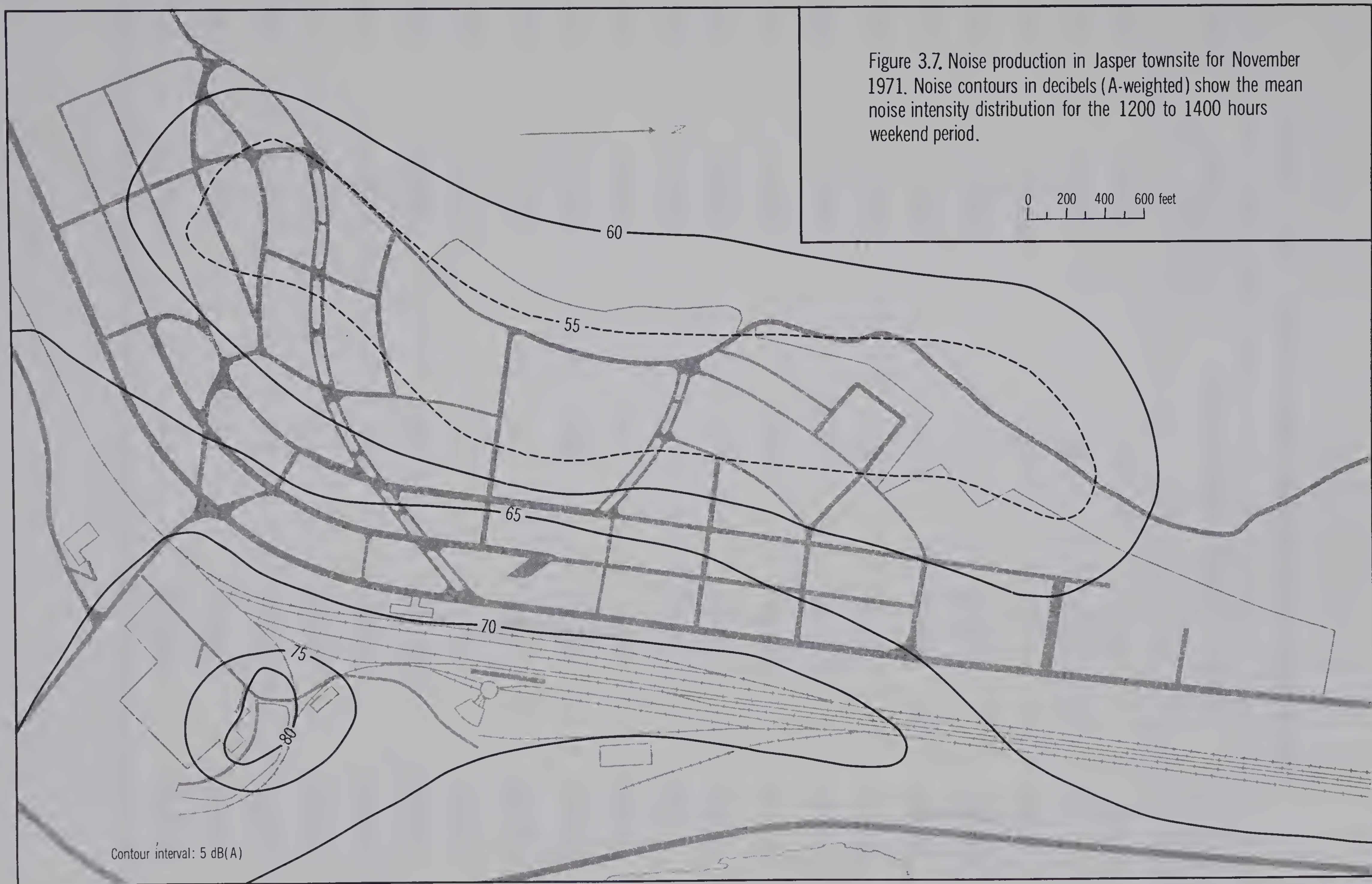


Figure 3.7. Noise production in Jasper townsite for November 1971. Noise contours in decibels (A-weighted) show the mean noise intensity distribution for the 1200 to 1400 hours weekend period.

TABLE 3.2. NOISE DATA FROM VALLEY TRANSECTS

Site	Elevation Ft. Above S.L.	Noise Mean	Noise Range	Noise Climate
11	3,985	40	37-43	38-41
12	3,900	49	43-52	46-50
13	3,800	68	64-75	66-72
14	3,460	56	53-63	56-60
15	3,480	50	43-57	49-53
16	3,480	52	45-60	49-54
17	3,640	62	55-69	58-64
18	3,555	45	39-52	42-46
19	4,305	50	45-57	48-53
20	5,120	49	46-55	48-51
21	5,430	42	39-47	40-44
22	6,100	48	43-56	47-52
23	6,640	--	49-70	52-66
24	3,715	40	37-45	39-42
25	3,510	42	39-48	40-43
26	3,470	45	44-48	45-46
27	4,220	61	57-68	59-64
28	5,025	55	52-63	53-58
29	6,070	53	50-58	51-55
30	6,710	48	40-59	43-54

single recordings taken at the individual sites.

Caution is required when evaluating the data. In contrast to the townsite case, valley samples have a large vertical and areal distribution. The potential complications arising from the existence of a complex sound field in the valleys become increasingly significant as the study area is expanded (Section 2.2). Wind interference with the monitoring process proved to be a major problem in this context. The mean noise intensity at site 23, for example, could not be considered to be significant, since it fell outside the actual noise climate as a result of wind-induced fluctuation within a large range. Due to limited time, and problems in negotiating difficult terrain, it was not always possible to limit the sampling to the same, specific time period for all the sites. Thus, little control could be exercised over the level of activity being monitored; variation in the data from site to site might well reflect variation in noise production rather than the differing response characteristics of the sites themselves. It would, therefore, be unrealistic to compare the individual readings for the purpose of uncovering the noise distribution pattern in this section of the valley system, particularly since the data represent only one reading per site.

3.2.2 Noise Diffusion in The Valley System

The data in Table 3.2 provide information on the extent of noise penetration in the valleys. At all sites

along the transects, the presence of a noise factor was perceptible. Noise interference was generally present in the form of raised sound pressure levels, with individual sources blending into an undifferentiated background level and superimposed on the natural sound pattern. This situation was best developed at the higher sites, particularly on Signal Mountain. Evaluation was done with reference to readings taken in natural settings outside the valley system; sound pressure levels ranged between 25 and 38 dB(A) - characteristically lower than levels registered in the transects.

Sound pressure levels generally increased with decreasing distance from the main areas of activity in the valleys. The diffused background noise was resolved into distinct noise components; at site 20 (el. 5,120 ft.) and at lower elevations, it became possible to distinguish between urban, and transport noise production originating from the highway, access roads, and railroad.

Intensity increments were not in phase for sites east and west of the townsite on the Athabasca River valley transect, although these sites were monitored under similar conditions of weather and noise production. Sites 11 and 12 show approximately the same noise conditions as were found for sites 20 and 21, respectively, even though the latter two sites were located significantly higher and further from the same noise sources. This difference was the result of the shielding provided for sites 11 and 12 (as well as site

24 in the Miette River valley transect) by the escarpment located directly west of the townsite. In contrast to site 13, located on the escarpment and in the direct path of sound waves originating to the east, sites 11 and 12 would receive a great proportion of diffracted, indirect waves.

3.2.3 Transportation Noise Production in the Valley System

Motor vehicle movement in the valleys had a decisive influence on the noise characteristics found along the transects. The anomaly that appears to exist in the intensity levels for sites 25 and 26 in contrast to the other locations on The Whistlers resulted from a variable traffic flow on the Yellowhead route. The volume was light and intermittent at the time the lower two samples were taken but heavy and continuous in the other cases. The high levels recorded at sites 27 through 30 were produced, primarily, by the high frequency 'whine' emitted by tires of heavy commercial vehicles. High frequency waves have a rapid dissipation rate in the atmosphere, a fact that is shown by the drastic reduction in intensity through consecutive sites. Closer to the highway, the whine from the tires was replaced by the lower frequency--high intensity rumble produced by diesel engines.

Transect and other sites situated alongside the highway were monitored for the noise produced under various conditions of traffic flow. The measurement of individual, heavy commercial vehicles, travelling at an estimated speed of 60 miles per hour, produced intensity maxima ranging between 86 and 91 dB(A). Levels recorded for private cars

under the same conditions ranged between 74 and 80 dB(A). Mixed traffic flow produced mean intensities ranging between 78 and 89 dB(A), depending on the volume and composition of the flow. The greatest absolute intensity ranges were recorded at the east and west gates of the Park; ranges of twenty five decibels or more were produced by accelerating and decelerating trucks, with fluctuations being mainly produced by gear shifting and the release of air brakes.

Noise traces at sites situated high above and/or at a distance from noise sources, were not necessarily confined to the diffuse, indistinct mixture described above. Aside from the whine recorded at the higher sites on The Whistlers, the noise produced by the passage of trains through the valley system could be distinctly identified. In fact, the noise was not confined to the valley system, but penetrated into adjoining areas. Thus, the passage of a train in the Miette valley could be heard in the Tonquin Valley, eight miles south of Geike, where the noise emitted spilled into the region occupied by Meadow Creek (Inset Map).

The capacity of noise to be transmitted over large distances can be seen in the upper trace of Figure 3.8. The noise from a westward-moving freight train was recorded at site 28. From an intensity maximum of 76 dB(A), recorded at the time the train was directly opposite the sound meter, intensity fell through two - 10 dB meter attenuations; the level first dropped below 60 dB(A) at a transmission

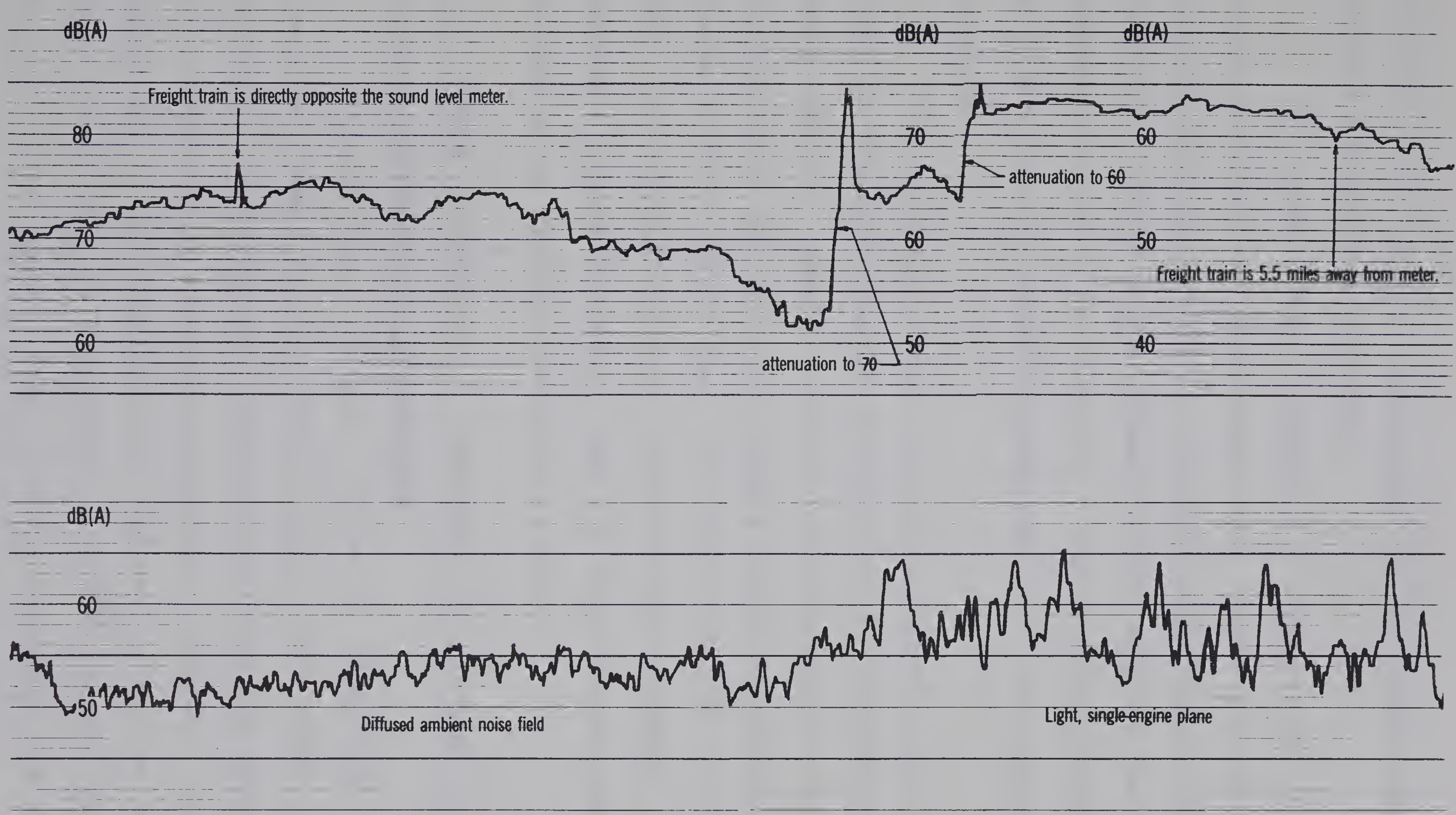


Figure 3.8. Noise traces generated by train and airplane movement through the valley system. The upper trace records the movement of a westbound freight train in the Miette River valley. The lower trace demonstrates the superimposition of a distinct noise source (airplane) on the diffuse ambient noise environment in the Athabasca River valley.

distance of 5.5 miles. (The trace had to be shortened to show the attenuation sequence.)

The lower graph in Figure 3.8 demonstrates the changes in the noise environment that occurred at site 22 with the superimposition of a distinct directional source--a low-flying, single engine plane in this case--on the diffuse background noise in the vicinity. The increased noise range and fluctuation is clearly associated with the appearance of the plane.

In contrast to rail and road transport, air traffic is not an important factor in the noise environment of the valley system. Jasper airfield has an emergency designation, is unattended, and does not possess radio, navigational aids, or snow removal facilities. Its use is limited to daylight hours. Air traffic volume is small, even in summer, and consists of light aircraft. The air strip may be eventually replaced by an airfield outside the Park.

3.2.4 Noise Attenuation by Topography and Vegetation

3.2.4.1 Attenuation by Topography

An important influence exerted by topography on the noise environment is the attenuation of sound waves. The absorption and reflection characteristics of the ground surface over which sound was transmitted were not measured, largely due to the complexity of the variables involved. Ground attenuation is a function of the structure and the covering of the ground, both of which determine its acoustic

properties. It is also influenced by the heights of the noise source and meter above the ground (Kurze and Beranek, 1971).

A major attenuation factor is caused by the effect of topographic obstruction on wave transmission. Shielding from the direct wave path is provided by a break-of-slope along the ground, with the shielded areas receiving distorted waves by diffraction and/or turbulence.

Figure 3.9 demonstrates the dissipation resulting from a major break-of-slope situation. The area, in this instance, was located near site 25. The Miette River formed the sound source for the superimposed traces. At the location for graph A, a direct line of sight existed to the source; a break-of-slope shielded site B from the direct path of the sound waves. The reduction in intensity at site B, and the increased variability resulting from the distortion caused by turbulence and diffraction is clearly evident.

Another case of topographic shielding occurred at sites 17 and 18 (Table 3.2). The latter site was located in a hollow surrounded by the slopes of Signal Mountain on the west and south, and by a shoulder to the east. Site 17 was located on a bare outcrop on the shoulder, 85 feet above site 18 and in the direct path of sound waves originating in the valley. This spatial relationship is shown in an aerial view through Figure 3.10. The 17 dB differential for the two sites could not be attributed to the shielding effect of the shoulder alone, since site 18 was set in a stand of aspen

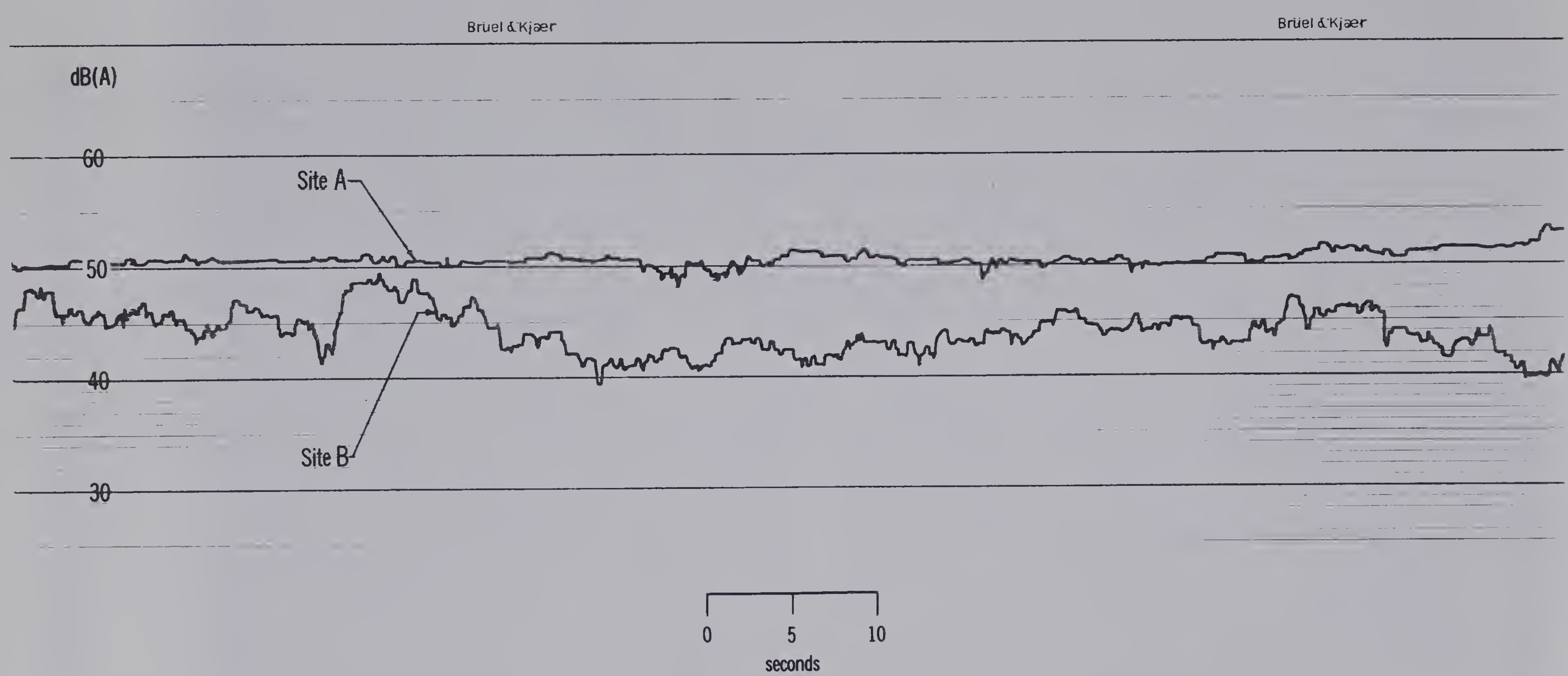


Figure 3.9. Sound wave attenuation caused by a topographic obstruction. Monitoring at site A involved a direct line of sight to the particular noise source; a break-of-slope shielded site B from this same source.

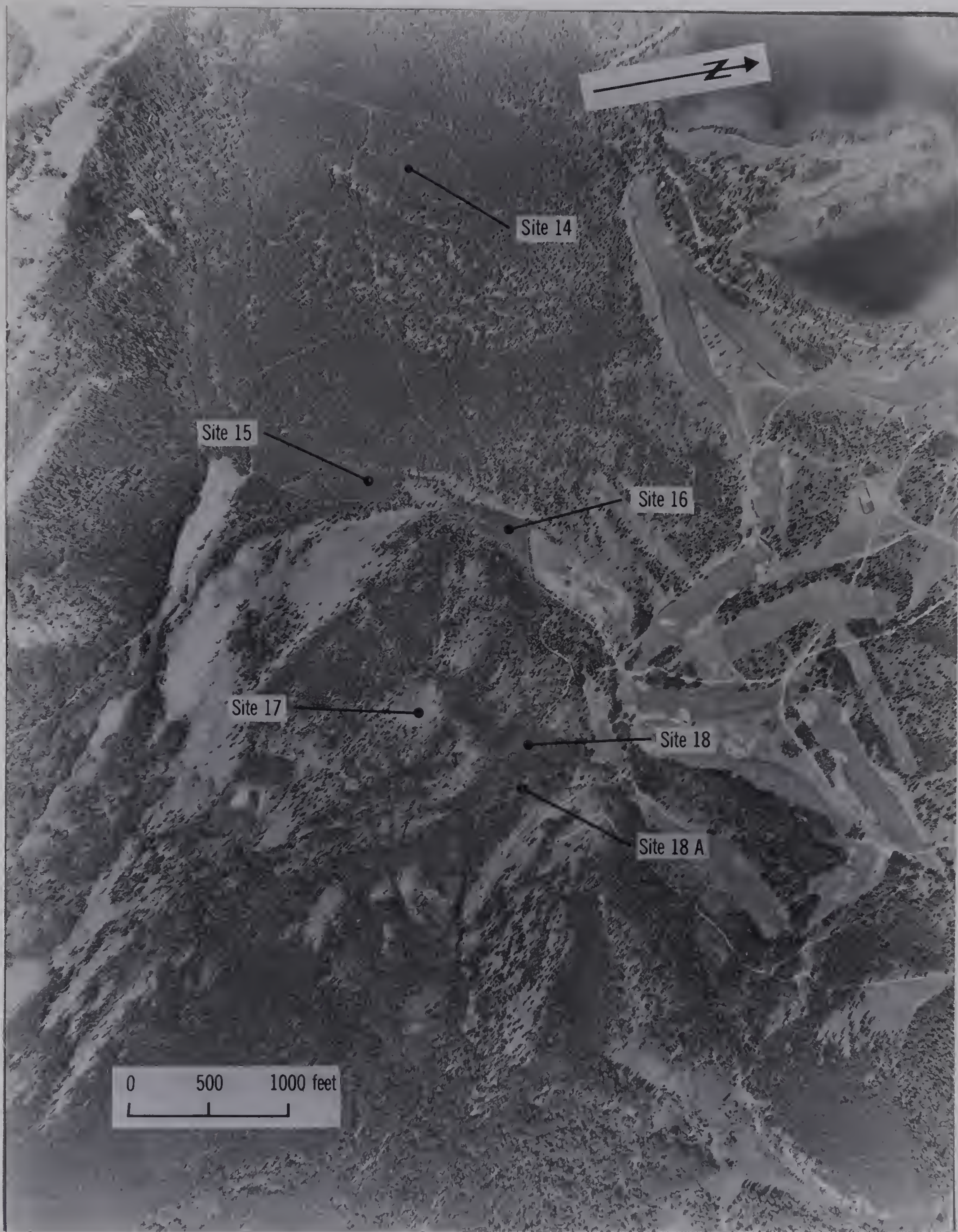


Figure 3.10. Area analyzed for attenuation characteristics of vegetation cover.

poplar (Populus tremuloides). Another site was therefore monitored in the hollow (18A), in a spot free from interference from the stand of trees; intensity reduction between sites 17 and 18A amounted to 10 dB, twice the value obtained in the situation discussed previously. The difference in the shielding effect is one of degree rather than kind. In both instances, shielding was due to a break-of-slope, the change being much greater in the second example.

3.2.4.2 Noise Attenuation Due to Vegetation

The area shown in Figure 3.10 was studied in an attempt to find the attenuation caused by forest cover. Sites 14 through 18 were used for the following reasons: the total relief difference for the sites is only 180 feet; the sites were located along the transect near the valley floor over a distance of about four thousand feet. This grouping over a relatively small vertical and horizontal distance, in addition to a similar orientation among the sites, with regard to the noise sources, would tend to produce a uniform reception of noise in the area, and minimize complications with the sound field. Readily accessible, the sites could be monitored within a single time period, eliminating to a great extent the problem of monitoring under conditions of great variation in the noise being produced. (Other sites on Signal Mountain, originally surveyed for noise attenuation resulting from their vegetation cover, were discarded for lack of one or more of the

above mentioned factors.)

Vegetation characteristics were studied by using a randomly chosen 10 - by - 10 meter quadrat at each site; only the tree layer was involved in the analysis. Several of the measured parameters are presented in Table 3.3. With the exception of site 18, which had a layer of largely dead wolf willow (Elaeagnus commutata) along with the more dominant species of aspen poplar, sites were located in pure stands of timber. The number of trees in each quadrat, and the percentage of the total quadrat area shaded or occupied by the trees, indicate the density characteristics of the stands. Sites 17 and 18A, both without tree cover, are included as reference points in relating Tables 3.2 and 3.3.

An incongruity appeared between sites 16 and 18: the latter, with the higher density characteristics of the two, has an attenuation level of 7 dB, as compared to a 10 dB reduction in intensity at site 16. The higher reduction at site 16 was due to the fact that the sound waves had to penetrate and travel through a greater distance through timber before reaching the meter. The result was a considerable dissipation of intensity. Site 18, on the other hand, received waves which travelled unobstructed to the rock shoulder, and were then diffracted into the hollow. The clump of trees at site 18 was not of sufficient size to cause an attenuation of more than 7 dB. In fact, considering the size of the stand, this drop of 7 dB is surprisingly large.

TABLE 3.3. FOREST COVER CHARACTERISTICS OF QUADRATS ANALYZED AND NOISE ATTENUATION PRODUCED BY VEGETATION

Site	Dominant Tree Species	Presence of Shrub Layer (x)	No. of Trees in Quadrat	Percent of Quadrat Area Shaded or Rooted	Height of Stand (ft)
14	Pinus contorta var. latifolia	X	34	70	25
15	Pinus contorta var. latifolia	X	32	70	25
16	Populus tremuloides		21	60	35
17			nil	nil	nil
18	Populus tremuloides	X	28	90	40-45
18A		X	nil	nil	nil

The intensity variation recorded for the sites indicated a definite dissipation due to the tree cover in the area. This attenuation appears to be related to the types of species composing the tree layer, as well as to the structure of the particular stands. Documented research into the attenuation capacities of tree zones (forests) has shown the significance of density variations. The average attenuation recorded for very thick forests (Canadian cedar, pine, spruce and deciduous forests; U.S.S.R. pine forest) varied between 10 and 25 dB per 100m at frequencies below 2,000 Hz (Embleton, 1963). For less dense arease (average for all types of U.S.A. forests) attenuations of 5 to 12 dB per 100m occurred at corresponding frequencies (Hoover, 1961). Deciduous forests with bare trees produced attenuation levels of 0 to 5 dB for the frequency range (Kuttruff, 1967). At any given frequency, however, large differences were found for Canadian, American, and Russian forests having a similar composition of species and density characteristics; no satisfactory explanation has been found for this differential in attenuation. The small number of observations used in this study is not meant to provide representative values in any sense; it is simply being used to demonstrate the existence of wave dissipation in the area, and links this attenuation to the demonstrable influence of the vegetation cover on sound and noise transmission.

CHAPTER 4

NOISE AS A FACTOR IN PARK PLANNING

4.1. Noise as a Pollutant

It has been pointed out that the production of noise interferes with the natural sound environment of the Park. By causing an unnatural change in the sound system, and a degradation of the Park environment, this by-product of human activity can be justifiably considered to be a pollutant. It conflicts with the principle of environmental conservation embodied in both national park policy and legislation. The underlying philosophy in Park management is contained in the often quoted Section 4 of the National Parks Act (1930) which states that

> The Parks are hereby dedicated to the people of Canada for their benefit, education and enjoyment, subject to the provisions of this Act and the Regulations, and such Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations.

The basis of this dedication to both present and future generations, is the provision of a natural, unimpaired Park environment. This primary purpose is reiterated in section I and II of the comprehensive statement on National Park Policy (1964). By definition a pollutant is a contaminant and can therefore cause the deterioration of a natural environment. The presence of noise in the sound environment of the Park has the potential to cause damage in two ways: by reducing, or interfering with the enjoyment of the Park

environment, and by affecting the wildlife characteristics of the Park.

A primary attraction of national parks should be the opportunity offered the public to experience and enjoy a natural environment. The perception and appreciation of such an environment will vary among individuals. Awareness of and reaction to the existence of a noise factor in a supposedly natural park environment will depend on psycho-acoustical variables (Chapter 1) as well as the particular purpose in visiting the park. By being an unnatural element, noise has the potential to interfere with or reduce enjoyment of such a visit. Regardless of the value placed upon it at any particular moment, the natural environment, including the ambient sound system, should be maintained free, as far as possible, from extraneous influences. The provision for an unaltered system is necessary if the public's right to experience and enjoy a major national heritage is to be insured.

Wildlife is an important element of the park environment, and its preservation is essential if the natural quality of the park is to be maintained. The auditory characteristics of various fauna and their response to noise have been studied under laboratory conditions. Little work has been done, however, on startle response under natural conditions, or on the behaviour changes induced by long-term exposure to noise and the effect of such exposure on the survival success of a wild population.

The process involved in obtaining relevant data on wildlife response would be particularly difficult in the park context. The population characteristics of a particular group of animals ascertained to have been unaffected by human activity would have to be known in terms of several generations in order to establish the population dynamics of the group. It would then be necessary to subject the group to a controlled noise environment. The problems involved in these procedures, in establishing a control group, in analyzing both short-term and long-term changes, and in accurately relating these changes to the presence of noise, would obviously be of a major magnitude. Response characteristics may be expected to differ among species, although all would probably tend to have a startle response involving the unnecessary expenditure of energy. Sound is the main sensory deference for ungulates, while the large carnivores may react as much to the smells associated with people, as to the noise produced by their activity.

The presence of human activity may act both to attract and repel wildlife. Other factors aside from noise, such as curiosity or the availability of food through roadside feeding, and at campgrounds or garbage dumps, may act to draw animals to the site of human activity. Such attraction can have harmful consequences. Bears that are persistently attracted to the townsite or campgrounds are shot. This destruction, although far smaller (in terms of numbers) than that which occurs through collision with trains and

motor vehicles, remains an unnecessary attrition of the park ecosystem. Long-term damaging effects may result from advertently or unintentionally supplying animals with food. Regular provision of such food (with the townsite garbage dump being an outstanding example of a readily accessible, year-round supply) may lead to dependence on unnatural sources.

In repelling, noise may cause the displacement of a particular animal or group of animals. This may place an unnecessary stress on the animals by exposure to potentially harsher environmental factors, such as inferior range conditions or conflict with another population or species.

Regardless of the response, noise induced behavioral changes are unnatural, and therefore detrimental to wildlife, and permanently impair the park environment.

4.2 Noise Control

4.2.1. Noise Reduction

A major means of noise control in the park involves reducing the noise output. Since noise production is associated with human activity, noise reduction could be achieved by regulating the type and level of human activity permitted in the park. Although restrictions on forms and volume of activity have been applied in the land use management of the park, the role of noise control has not been emphasized in the management process. Similarly, no specific consideration has been given to the noise factor in national

park policy or legislation. The lack of attention to noise control, both in legislation and in management procedures, points to an underestimation of the importance of noise production in the park environment.

Moreover, the noise factor will increase in severity and complexity in parks like Jasper which are subjected to ever increasing pressures on their natural resources. In Jasper National Park, these pressures pertain to two main sources: the demand for (outdoor) recreation, and the existence of major transportation networks within the park. Both demand and volume of flow are likely to keep increasing in the near future. The increasing demand for outdoor recreational activity is shown by the rising visitor attendance. The demand of the majority of park visitors is still for modern accommodation with all the conveniences common to life in the cities. Only a small proportion participate in outdoor recreational activities oriented toward wilderness use and enjoyment (National Park Policy, 1964). Noise production will differ greatly between these two groups due to the use of different facilities and the spatial distribution within the park area. Differences will exist, as well, within each group; among wilderness users, a large variation in noise output will occur between the cross-country skier and snowmobile user.

In contrast to private traffic, commercial traffic makes an important use of the park as a corridor linking the west coast to the interior. Figure 3.4 showed the high

volumes for both types of traffic flow in the park. In contrast to the large seasonal fluctuations for private vehicles, the commercial flow is relatively evenly distributed over the entire year. This commercial traffic is likely to increase in the future. The Yellowhead route is being promoted by the Yellowhead Highway Association, among others, as providing better access to the coast than do the mountain routes further south. With smaller grades, fewer winding stretches, and a lower frequency of road blockage due to adverse weather conditions, the Yellowhead is preferred as a trucking route. Should it be used as a major alternate route for the movement of grain exports to the coast, particularly if Prince Rupert is developed as a deep-sea port for the export of bulk commodities, grain unit trains will substantially increase the volume of freight moved by rail through the park. As in the case of recreational demand, a major by-product of such increased activity will be the production of an intensified noise environment.

4.2.2 Noise Confinement

An additional means of noise control would involve the confining of its production to specific locations in the park. This would tend to reduce the area affected by particular noise sources. In some instances, noise could be confined to a limited area through the attenuation caused by topography and vegetation. The appropriate use of natural barriers could help confine noise generated within

a campground, for example, while isolating the campground from external sources.

Control over noise distribution on a larger scale could be achieved by park zoning. A zoning scheme has been developed for the park (Jasper National Park Provisional Master Plan, 1970). This scheme, with its proposed limitations on activity and land use, could ultimately control noise propagation. However, increased pressures through recreational demand, could result in the reduction and displacement of zones devoted to the preservation of the natural environment by the gradual expansion of more intensively used areas. A spatial variation involving increasingly high noise production can be expected to occur in conjunction with the following arrangement of the designated zones: Class I (Special Area), Class 2 (Wilderness Recreation Area), Class 3 (Natural Environment Area), Class 4 (General Outdoor Recreation Area), Class 5 (Intensive-Use Area).

The main problem associated with noise control through zoning is the tendency for sound diffusion in the atmosphere. Various meteorological factors help determine the diffusion characteristics of sound (Chapter I); in conjunction with landscape influences, these factors can produce a complex sound field, as in the case of the study area (Chapter 2). The ability of high intensity noise to travel over long distances has been shown in the data obtained for the valley transects (Chapter 3); in

the Athabasca-Miette valley system, this ability means, in effect, that noise from a Class 5 location (the townsite and surrounding area) could be expected to penetrate into locations designated as Class 2 and 3 regions. Noise generated by transport networks in the valley system, would likely reach Class 1, 2, and 3 areas in the valleys.

This problem would not be limited to a particular valley system, but would occur in all areas containing human activity. It would arise in all instances of road development; noise diffusion would not be limited to the width of pavement, but would invade adjacent (wilderness) areas in spite of the provision of Class 3 buffer zones.

Zoning, by itself, is an insufficient method for controlling the noise problem--it must be applied in conjunction with noise abatement procedures in the different zones. The realization of this important relationship (although not in the context of noise control) is shown in the proposals outlined for the Provisional Plan:

> The capacity of each zone to withstand visitor use will be established. Development of facilities will be limited to retain the park's natural features and atmosphere. Ultimately it may be necessary to limit the number of visitors to certain areas of the park at a given time.

Reducing noise production, and regulating its distribution are two different, but related facets of the same problem--the need to control its environmental and recreational impact.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The foregoing chapters have presented the results of a noise study carried out in Jasper National Park in the summer of 1971. The study was undertaken to determine the extent and individual sources of noise production in the park, and to identify the factors influencing its distribution. The potential damage to the park environment resulting from noise pollution was evaluated, as well as, the possibility of achieving a measure of control over the noise component through the implementation of proposed park plans.

The phenomena of sound and noise result from the vibration of particles in a medium such as air. The perception of sound is determined by the complex interaction of psycho-acoustical variables, especially the physical properties of pressure and frequency. The evaluation of sound as constituting a noise, i.e., an undesired sound, is a value judgment that will differ from person to person. The physical dimensions and psycho-acoustical factors that produce the phenomena of sound, noise, and hearing are discussed in Chapter 1.

The distinction between sound and noise is applied in Chapter 2 to the case of Jasper National Park by distinguishing between ambient sounds produced by natural elements in the park, and sounds produced through human activity. The latter are

classified as noise due to their extraneous origin and unnatural presence in the park. These produce an unnatural noise environment which is superimposed on the natural sound environment found in the park.

The existence of a major noise environment in the park can be traced to a combination of factors that in some ways are characteristic of the parks found in the Rocky Mountains region. The park straddles a pass through the eastern range of the Rockies that is used as a link in a major transcontinental rail and highway route, utilized by both commercial and private traffic.

Ever increasing leisure time and mobility in our society has helped to create a great public demand for outdoor recreational space and facilities. The proximity of major urban centers to the park, and the development in the 1960's of a modern highway system linking the park to these centers has led to a rapidly rising visitor attendance rate. The construction of an improved Highway 93 resulted in an increased influx of tourists from adjoining Banff National Park, particularly in the number of visitors from the United States. The annually increasing traffic and visitor volume has led to an accelerated development of commercial and recreation facilities and the corresponding intensification of noise production.

A study area was chosen comprising the Athabasca-Miette valleys, a location which allowed mobility and relatively quick access in the face of a limited time

factor. The valley system acts as a (transcontinental) transport corridor, and as an area of commercial development, including outdoor recreational facilities and Jasper townsite, the focal point of human activity in the park.

Sound production was monitored with a sensitive sound level meter, the sounds being permanently recorded on magnetic tape. Analysis of noise components was done from the graphic traces developed from the tapes with a level recorder. Noise samples are described in units of dB(A) as a result of using the A-weighted network, a scale giving a meter response that closely approximates the auditory characteristics of the human ear. A detailed discussion of the monitoring equipment is given in Appendix II.

Ten sites were monitored in the townsite for a total of eighty samples representing both week day and weekend conditions during July and November 1971. Another twenty samples were taken on two valley transects. In all, one hundred fourteen recordings were used in determining the characteristics of the noise environments in the urban and valley systems (Chapter 2).

The frequent occurrence of strong winds and rainfall presented a major complication in the recording procedure by masking noise production and interfering with the monitoring of this noise by the sound meter. Meteorological factors, particularly thermal and wind gradients in the atmosphere, were also responsible in generating a complex sound field

in the valleys by altering the transmission pattern of sound waves. The effects of such interference (discussed in Chapter 2) helped to produce variations in the sound reaching a particular site.

A full discussion of the noise environments found in the urban and valley systems is given in Chapter 3. Two major patterns were discernible in the townsite. The first represented the variation in noise parameters which result from differences in the land use. As expected, residential areas had a generally lower noise production than commercial sites; maximum recorded intensities reached 85 - 95 decibels in the latter during the July period, in contrast to maxima of 70 - 80 decibels for residential locations.

The second major pattern represented the seasonal change from summer to fall, corresponding to the change from the major annual tourist season to an off-season period. A large reduction in the noise components occurred at all residential and commercial sites with the arrival of the off-season period. Individual sites displayed a strong uniformity in noise production within each major period. Daily fluctuations were negligible, in contrast to urban centers which do not reflect the presence of such a strong seasonal control over activity and noise levels.

Transportation activities and facilities were important contributors to the overall urban noise system. Railroad transport formed a consistent and dominant noise source,

due to both localized activity in the yards, and the passage of trains through the townsite. The moving trains generated distinctive noise traces in approaching or departing from the area, with track grade determining, in part, the characteristic patterns that were generated.

Local motor vehicle traffic in the townsite was responsible for a consistent "quasi-steady-state" flow, and the isolated peaking of "discrete moving noise sources"; usually attributed to heavy commercial vehicles. Unlike railroad movement, motor traffic displayed a strong seasonal fluctuation. It was the principal factor in maintaining the uniformly high levels at commercial sites during the summer. The large reduction in traffic volume associated with the arrival of the off-season helped re-establish a subdued noise environment; daily fluctuations which had been masked during the summer by the consistently high intensities of the tourist period, now re-appeared.

When transect samples were taken, the existence of a complex sound field in the valley system became evident by the control it exercised over noise diffusion: intensity increments were not in phase with decreasing distance from noise sources, and sound wave diffraction interfered with wave dissipation (Appendix I).

The presence of a noise factor was discernible at all sample sites. At higher elevations this usually took the form of an undifferentiated background level superimposed on the natural sound environment. With decreasing distance and elevation from noise sources in the valleys, the diffuse

field resolved into distinct, directional components.

As in the case of the townsite, noise from transportation activity was a major component in the valley system. Highway traffic, monitored under conditions of heavy flow for a varying composition, created intensities ranging from 78 to 89 dB(A). Individual diesel trucks produced maxima ranging from 86 to 91 dB(A), with the largest absolute ranges occurring through the acceleration and deceleration at the park gates.

The noise generated by the movement of trains through the valley system was perceptible not only at transect sites, but also in adjoining valleys, illustrating the capacity of noise to be transmitted with only a small rate of dissipation over large distances.

An important factor controlling the distribution of noise in the valleys was the attenuation of sound waves by topography and vegetation. Significant alterations in the transmission pattern of noise was caused by the interception of sound waves through topographic features. The diffusion capacity of sound within forested areas depends largely on the density and structural characteristics of the vegetation. Various examples of the attenuation produced by topographic features and vegetation are presented in Chapter 3.

The existence of a strong noise environment in the park has various ramifications for the park's most important asset--its natural environment. The preservation of an unimpaired environment for the enjoyment of this and future

generations is the basic tenet of national park legislation and policy. By being a pollutant, noise has the potential to detract from the public's enjoyment of the park's natural setting, as well as the potential to impair the natural environment through its effects on wildlife.

The significance of the noise factor in the park in terms of the natural environment, and potential methods for its control are evaluated in Chapter 4. Although noise cannot be completely eliminated from the park without the exclusion of human activity, control over its production and proliferation could be achieved by introducing a more discriminating designation of activities considered to be 'appropriate' to the park setting and environment.

Reducing the effect of noise would involve the strict limitation of both levels and distribution of various activities. Considering the particular circumstances and pressures brought to bear on Jasper Park, a zoning scheme, such as the one envisioned in the Provisional Master Plan, would appear to offer the only feasible alternative to the prospect of an uncontrolled noise environment. Various alterations and safeguards would be required, however, before the present plan could be expected to successfully cope with the problems of noise abatement.

Considerable scope exists for further investigation into noise environments operating within park systems. In Jasper Park, the monitoring of noise production should be expanded both in area and in the detailed coverage of various

sources, especially in the case of outdoor recreation. Inquiry should be extended to cover the winter season and related activities. The utilization of automatic recorders would greatly facilitate the compiling of data, particularly about the diffusion characteristics of waves within complex sound fields. A comprehensive analysis of noise attenuation by various characteristic topographic and vegetation features representing a range of park landscapes is required. Detailed noise perception studies should be undertaken to determine the factors that influence the perception and reaction to noise environments within the park. The complex interaction between noise and wildlife offers biologists a virtually unexplored area of research.

The noise factor is only one aspect of the impact of human activity on the natural environment in the park. This impact is symptomatic of what is the outstanding problem facing the national park system today--the need to create a balanced juxtaposition between ever increasing recreational needs and demands on the one hand, and the preservation of nature and wilderness areas, on the other.

BIBLIOGRAPHY

BIBLIOGRAPHY

Barkhausen, H., "A New Sound Measurer," Zeitung for Technische Physic, Volume 7, Number 12, 599-601: 1927, Zeitshrift des Vereines Deutscher Ingenieure, Volume 71, Number 42, 1471-1474.

Bauman, K., 1971, "Urban Noise as a Factor in Planning," unpublished Master's thesis, Edmonton, University of Alberta, 154 pp.

Beranek, L. L., 1954, Acoustics, New York: McGraw-Hill, 481 pp.

Beranek, L. L., 1971, "The Measurement of Power Levels and Directivity Patterns of Noise Sources," Noise and Vibration Control, L. L. Beranek (ed.), New York: McGraw-Hill, 138-163.

Bolt, Beranek and Newman, Inc., 1967, Noise in Urban and Suburban Areas, Washington, D.C., U.S. Department of Housing and Urban Development, 51 pp.

Boring, E. G., 1935, "The Relation of the Attributes of Sensation to the Dimensions of the Stimulus," Philosophy of Science, Volume 2, Number 2, 236-245.

Broch, J. T., 1969, Acoustic Noise Measurement, Soborg, Denmark: Brüel and Kjaer, 138 pp.

Bruce, R. D., 1971, "Field Measurements: Equipment and Techniques," Noise and Vibration Control, L. L. Beranek (ed.), New York: McGraw-Hill, 74-99.

Canada, Government of, 1930, The National Parks Act, 20, Geo. 5 Chapter 33: 1952 Revised Statues of Canada, 3, Chapter 189, Ottawa, Queen's Printer, 3969-4030.

Canada, Government of, 1967, National Parks Policy, Ottawa, National and Historic Parks Branch, Department of Indian Affairs and Northern Development, 32 pp.

Canada, Government of, 1968, Climatic Normals, Volume 2 - Precipitation, Toronto, Meteorological Branch, Department of Transport, 110 pp.

Canada, Government of, 1970, Jasper National Park Provisional Master Plan, Ottawa, National and Historic Parks Branch, Department of Indian Affairs and Northern Development, 20 pp.

Canada, Government of, 1971, Monthly Record, Meteorological Observations in Canada, Toronto Meteorological Branch, Department of Transport, January - December.

Davis, H., and S. Silverman, 1970, Hearing and Deafness, 3rd. ed., New York, Holt, Rinehart and Winston, 522 pp.

Embleton, T.F., 1963, "Sound Propagation in Homogeneous Deciduous and Evergreen Woods," The Journal of the Acoustical Society of America, Volume 35, 1119-1125.

Glorig, A., 1958, Noise and Your Ear, New York, Grune and Stratton, 152 pp.

Hirsh, I. J., 1952, The Measurement of Hearing, New York, McGraw-Hill, 364 pp.

Hoover, R.M., 1961, Tree Zones as Barriers for the Control of Noise due to Aircraft Operations, Report 844, Washington, D.C., Bolt, Beranek and Newman, Inc.

International Electrotechnical Commission, 1961, General Purpose Sound Level Meters, IEC/123, Geneva.

International Organization for Standardization, 1959, Expression of the Physical and Subjective Magnitudes of Sound or Noise, ISO/131, Geneva.

International Organization for Standardization, 1961, Normal Equal Loudness Contours for Pure Tones and Normal Threshold of Hearing Under Free-Field Listening Conditions, ISO/R226, Geneva.

Krech, D., and R.S. Crutchfield, 1958, Elements of Psychology, Berkeley and Los Angeles, University of California Press, 700 pp.

Kryter, K.D., 1959, "Scaling Human Reactions to the Sound of Aircraft," The Journal of the Acoustical Society of America, Volume 31, Number 11, 1415-1429.

Kryter, K.D., 1970, "Annoyance," Transportation Noises, A Symposium on Acceptability Criteria, Seattle, University of Washington Press, 69-84.

Kurze, U., and L.L. Beranek, 1971, "Sound Propagation Outdoors," Noise and Vibration Control, L.L. Beranek (ed.), New York, McGraw-Hill, 164-193.

Kuttruff, H., 1967, "Reverberation in Media with Irregularly Distributed Centres of Scattering, Especially in Reverberation Chambers Containing Suspended Scattering Elements," Acustica, Volume 18, Number 3, 131-143.

Land, J., and G. Jansen, 1970, The Environmental Health Aspects of Noise Research and Noise Control, Copenhagen, World Health Organization, 97 pp.

Nicol, J.I., 1970, "The National Parks Movement in Canada," Canadian Parks in Perspective, J.G. Nelson (ed.), Montreal, Harvest House Ltd., 19-34.

Peterson, A., and E. Gross, 1967, Handbook of Noise Control, 6th ed., West Concord, Massachusetts, General Radio Company, 282 pp.

Rodda, M., 1967, Noise and Society, Edinburgh, Oliver and Boyd, 113 pp.

Stevens, S.S., 1935, "The Operational Definition of Psychological Concepts,"The Psychological Review, Volume 42, Number 6, 515-527.

Stevens, S.S., and H. Davis, 1966, Hearing, New York, John Wiley & Sons, Inc., 489 pp.

Subcommittee on Vehicle Noise, 1970, Fundamentals of Noise and Vehicle Exterior Noise Levels, San Francisco, Western Highway Institute, 51 pp.

Weiner, F.M., C.I. Molme, and C.M. Gogos, 1965, "Sound Propagation in Urban Areas," The Journal of the Acoustical Society of America, Volume 37, Number 4, 738-747.

APPENDICES

APPENDIX I

GLOSSARY

Decibel: the non-dimensional ratio of two measures of sound power expressed as a logarithm to the base 10. Sound pressure level in decibels is equal to 20 $\log_{10}$ (P/Po) where p is the sound pressure level of a given sound, and p_o is an arbitrary reference level usually taken as 0.0002 dynes/ cm^2 (microbars), the minimum auditory threshold for normal young adults.

Diffuse sound field: a field within a large irregular enclosure or space that consists of a superimposition of sound waves traveling in all directions with equal probability. In reality, ideal diffuse fields never exist because there is always a net flow of power from the source to the places where the energy is ultimately absorbed (directivity pattern).

Doppler effect: the behaviour of sound produced by an object that is moving in relation to a listener. Each successive sound wave is emitted farther ahead on the path of the moving source. Although diffusion occurs in all directions at a constant speed, the waves are not concentric. Compressed in front of the moving object, they pass the observer at a higher frequency and pitch than those actually produced by the source. Behind the moving object the reverse situation occurs; the distance between waves is increased, the frequency decreased and the pitch lowered.

Free sound field: a field in a homogeneous isotropic medium free from boundaries. In practice, it is a field in which the effects of the boundaries are negligible in the area being monitored for sound transmission.

Frequency: the number of times that a periodic quantity repeats itself in a unit interval of time; the unit of frequency is the cycle per second (c/s), also called hertz (Hz).

Intensity: refers to a dimension of a stimulus, being the measure or magnitude of the stimulating agent. In the case of sound (waves), intensity is usually measured in terms of pressure or energy flow (power), the intensity level of sound pressure being expressed in decibels.

Loudness: the psychological response made by an observer to the physical intensity of sound, which enables sounds to be rated on a scale running from 'soft' to 'loud.' Chiefly a function of the intensity, it is also dependent upon the frequency and the composition of the sound.

Loudness level: the intensity level of a 1,000 cycle tone which sounds equal to the sound in loudness. Loudness level is measured in decibels or phons above the reference intensity of the 1,000 hertz tone.

Noise. physically, noise is defined as a complex sound with little or no periodicity; psychologically, it is usually defined as any annoying or unwanted sound.

Noise climate: the range of sound levels recorded for 80 per cent of the time (the sound levels between the 10 and 90 per cent levels). The 90 per cent level is an

indication of the ambient level which is mainly due to distant traffic activity, and the 10 per cent level is the result of intermittent sounds of higher intensity, whether from local sources, or the more distant components of trains or aircraft.

Octave: the interval between two sounds having a basic frequency ratio of 2 to 1.

Perceived noise level: the level in decibels assigned to a noise by means of a calculating procedure that is based on an approximation to subjective evaluations of 'noisiness'.

Phon: the unit for measuring loudness level of a tone. The number of phons is equal to the number of decibels that a 1,000 cycle tone is above the reference (threshold) intensity when perceived to be equal in loudness to that sound.

Pitch: the psycho-acoustical response made by an observer to the dimension of frequency enabling sounds to be rated according to a scale running from 'low' to 'high'.

Sound: an alteration in pressure, particle-displacement, or particle-velocity propagated in an elastic medium. Sound is also the sensation produced through the auditory mechanism in response to these disturbances.

Sound diffraction: or 'turning the corner' occurs when one set of sound waves use the edge of an obstruction (such as a topographic break-of-slope) as a pivot from which to generate a new pattern of waves. The edge of the barrier becomes a secondary sound source, transmitting waves of the same frequency and wavelength as the original set, but of a lower intensity. The new waves are projected into the

'shadow zone' behind the barrier, and also radiate into the path of the original set, creating zones of the interference.

Sound pressure: the force exerted by the movement of particles in an elastic medium. In the propagation of sound in air, sound pressure is the incremental variation above and below atmospheric pressure and is measured in dynes per square centimetre or microbars.

Sound pressure level: the level in decibels, 20 times the logarithm to the base 10 of the ratio of the pressure of the sound to the reference pressure usually taken as 0.0002 microbars--the threshold of human hearing acuity.

Sound refraction: the bending of sound waves caused by the existence of gradients (usually thermal) in the atmosphere. The speed of sound varies with the temperature of the transmitting medium; waves passing from cool to warm air will speed up. Waves crossing a thermal gradient will bend, the extent of such refraction being determined by the difference in temperature and the angle of movement.

Sound wave: an oscillation of pressure or stress produced by the sequential displacement of air molecules (or particles of any other elastic medium). Any vibration may be a source of sound, but sound waves can only be produced by the longitudinal vibration of transmitting of the medium.

APPENDIX II

SOUND MEASURING EQUIPMENT

The measurement of noise was carried out with a sound level meter (General Radio, Type 1551-C) that meets the international standards for general purpose sound level meters (International Electrotechnical Commission, IEC/123 - 1961). It is a compact, rugged, and easy to handle instrument, possessing a measuring range from 24 to 150 dB (re $20/\mu N/m^2$), and a frequency response ranging from 20 Hz to 20 kHz. The meter was mounted on a tripod, approximately 3 feet above the ground, with the microphone placed in a horizontal position. A windscreen, consisting of a foam ball 4 inches in diameter, was placed over the microphone to reduce the effect of wind interference. The monitored noise was recorded on magnetic tape with the use of a Uher 4000 tape recorder, a battery operated instrument that can record high frequencies without distortion. Operator and equipment noise error was kept to a minimum by placing the recorder on the ground behind the meter. Recordings were taken on the linear scale (no weighting being applied). All relevant information pertaining to a sample was spoken into the recorder at the time of monitoring.

Figure II.i shows the arrangement of instruments used in converting the monitored noise into a graphic trace. An example of such a trace is given in Figure II.ii.

Figure II.i. Sound measuring equipment: from left to right behind the sound level meter are shown the tape recorder, the microphone amplifier and the level recorder.

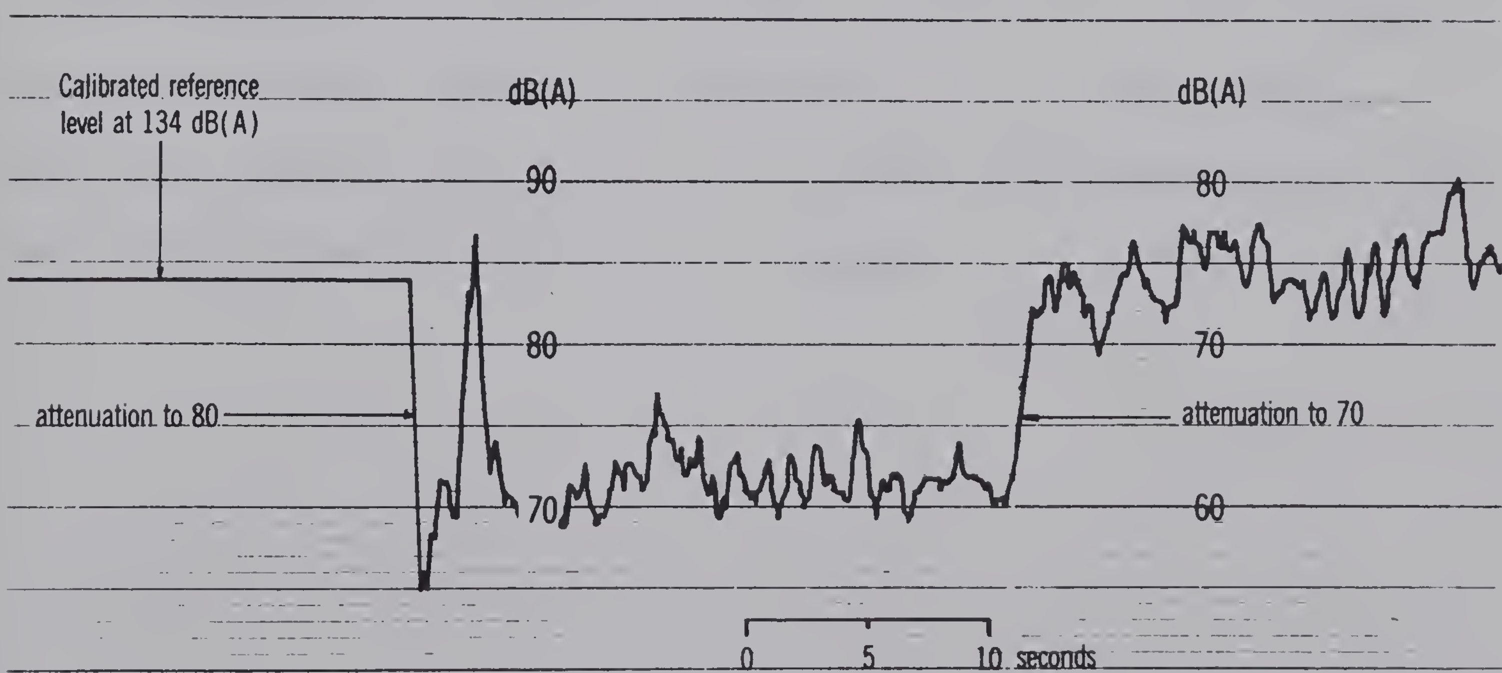


Figure II.ii. Noise trace components.

The recorded noise was fed through a high gain microphone amplifier (Brüel and Kjaer, Type 2603). The amplifier is equipped with weighting networks, allowing the introduction of the dB(A) scale at this point. The instrument was connected to a level recorder (Brüel and Kjaer, Type 2305) designed to accurately trace impulses in the frequency range of 2Hz to 200 kHz.

A graphic representation of noise intensities was produced on 100 mm wide charts, scaled into 1 dB intervals. The sound meter produces an output signal of 1,000 cycles. Through panel adjustment, it is possible to generate an output signal of 134 dB at the above frequency. This provides a calibrated reference level to which the various instruments can be adjusted. Aside from giving this reference level, the graph presented in Figure II.ii shows the 10 dB jump produced by attenuating the meter's response level from 84 to 74 dB in the presence of a uniform noise intensity. The graphic traces provided a means of determining mean intensities, intensity maxima and minima, the degree of fluctuation, and the duration period of specific levels.

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